MINERALS AND ENERGY BRANCH

REPORT OF ACTIVITIES

1999

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EDS. D. R. MACDONALD AND K. A. MILLS

NOVA SCOTIA
Natural Resources

Honourable Ernest L. Fage
Minister

D.J. Graham
Deputy Minister

Halifax, Nova Scotia
2000

Cover photo

Photograph of a gold nugget from the Whin Vein in the Blueberry Hill Mine, Tangier Gold District. This grain was one of many recovered from a 75 kg face sample of the 12-55 south-drift-west heading in April 1999. The calculated grade from this 45 cm wide chip sample across ~5 m of exposed face was 70.85 g Au/t. Much of the gold at Tangier, like this grain, has high fineness (~97% Au, ~3% Ag) and displays crystalline, wire, flake and massive textures hosted in clear to white massive quartz in bedding-parallel veins. Open spaces are still apparent within the grain. This gold grain shows minor deformation in the centre of the photo which is not apparent in the attached quartz. The image was taken with a Nikon SMU-U binocular microscope. The long dimension of the grain is 2.7 mm.

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Overview of the Geology and Mineral Resources of the Western Part of the Windsor (Kennetcook) Basin, Wolfville - Windsor Area (NTS 21H/01 and part of 21A/16), Hants and Kings Counties, Nova Scotia

R. C. Boehner, R. G. Moore[1] and C. Kennedy

Wolfville - Windsor Geological Map

A preliminary geological map (1:50 000 scale) of the Wolfville - Windsor area (NTS 21H/01 and part of 21A/16) was displayed at Mining Matters '99 in November 1999. This geological map (Figs. 1 and 2) will be an update of work by Crosby (1962). The new map is a compilation of recent geological mapping work (1980s to 1990s), undertaken at a variety of scales, by Dr. R. G. Moore, L. Ham and the late Dr. S. Ferguson. The map will accompany a report on the geology of the western part of the Windsor (Kennetcook) Basin in preparation by Dr. R. G. Moore. The report will further contribute to documenting and understanding the Carboniferous basin fill, especially the Windsor Group and Horton Group strata, as well as, to varying degrees, paleogeographic, tectonic and depositional settings. These data are fundamental in understanding the distribution of base metal deposits and other potential mineral, petroleum and water resources within the area.

The Wolfville - Windsor map area (Figs. 1 and 2) uniquely includes most of the major rock units constituting southern mainland Nova Scotia. These include the following (Fig. 3): Cambrian to Devonian metasedimentary and metavolcanic rocks of the Meguma Terrane; late Devonian peraluminous granitoid rocks of the South Mountain Batholith; sedimentary rocks of the Carboniferous Windsor Basin; Mesozoic (Late Triassic to Early Jurassic) Fundy Basin sedimentary and volcanic rocks; and locally, rare Early Cretaceous unconsolidated sand and clay. Unconformities of successive upper Paleozoic and lower Mesozoic basin fills are well represented. The map area also contains type and reference sections for many rock units including: the lower to middle Paleozoic White Rock, Kentville and New Canaan formations (stratigraphically above the Goldenville and Halifax formations of the Meguma Group); the Carboniferous Horton and Windsor Groups (Bell, 1929, 1958); and the Wolfville, Blomidon, North Mountain and Scots Bay formations of the Mesozoic Fundy Group. The area has had a long history of mineral exploration and mining as well as petroleum exploration. Exploration for metallic minerals, industrial minerals and petroleum continues in this prospective area. Currently, the utilization of geology in water resource evaluation and management is a developing application in this intensive agricultural and municipal growth region. Some recent references related to the geology of the western part of the Windsor Basin include Moore (1996), Martel and Gibling (1996) and Boehner (1994).

Windsor Basin

The Windsor (Kennetcook) Basin is a northeasterly elongated structural basin in central mainland Nova Scotia (Fig. 1). The Windsor Basin together with the adjacent Shubenacadie and Musquodoboit basins comprise the Minas Sub-basin (depositional) of Bell (1958). The prominent northeast-southwest structural trend merges and converges with a well-developed east-west orientation in the Cobequid-Chedabucto Fault System, which extends along the northern part of the Windsor and Shubenacadie basins. Early Cretaceous strata occur locally as fault-controlled erosional remnants in the nearby Musquodoboit and Shubenacadie basins and similar outliers may be discovered in the Windsor Basin. The Windsor Basin, like the Shubenacadie and Musquodoboit basins, is a small structural element of the late Paleozoic basin system in Atlantic Canada referred to as the Maritimes Basin. The basins are depositionally and structurally related and represent the present day erosional remnants of late Paleozoic overstep to the south onto the Meguma Platform with original depositional limits unknown.

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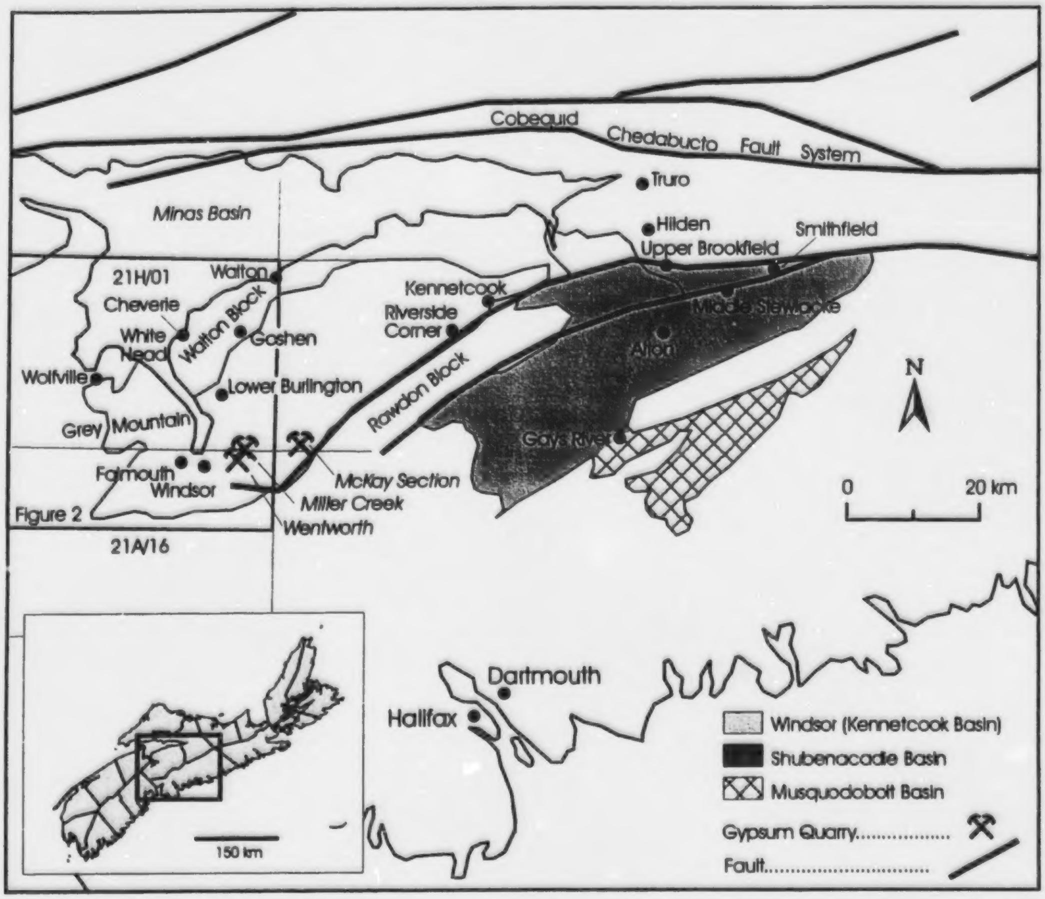

Figure 1. Location map of the western part of the Windsor Basin (NTS 21H/01 and part of 21A/16), Hants and Kings counties, Nova Scotia.

Deformation and structural complexity ranges from generally undeformed, gently folded rocks in the Musquodoboit Basin on the southeast, through to severely deformed rocks toward the northwest in the Windsor Basin (Fig. 1). This structural zonation reflects proximity to the Cobequid - Chedabucto Fault System and is important in controlling the location, limits and structural configuration of the Carboniferous strata and mineral deposits in the area.

The Windsor Basin contains up to 2000 m (stratigraphic thickness) of upper Paleozoic, primarily Carboniferous continental and marine sedimentary rocks. The basin underlies approximately 1500 km^2 of northeastern Kings County and western Hants County. The western part of the basin is included on the Wolfville - Windsor geological map (Figs. 1 and 2) and contains the type areas and type sections for the Carboniferous Horton and Windsor groups (Bell, 1929, 1960). The basin fill ranges in age from mainly Early Carboniferous (Tournaisian) with very minor Late Devonian, to Late Carboniferous (Westphalian B-C). The basin strata overlie, with angular unconformity, the Cambrian to Ordovician metasedimentary rocks, or nonconformably overlie the Late Devonian peraluminous granitoid rocks (Fig. 3). Contacts with the bounding basement blocks are complicated by syn- and post-Carboniferous fault movements. Age relationships between the South Mountain Batholith granitoids and the overlying Horton Bluff Formation in the western part of the basin, based on palynology and geochronology, indicate an apparently short time interval (10-15 million years in the Famenian) for batholith unroofing and erosion to provide sediment for the overlying Horton Bluff Formation.

The earliest basin fill (up to 1000 m in the east-central part of the basin) is dominated by coarse- to fine-

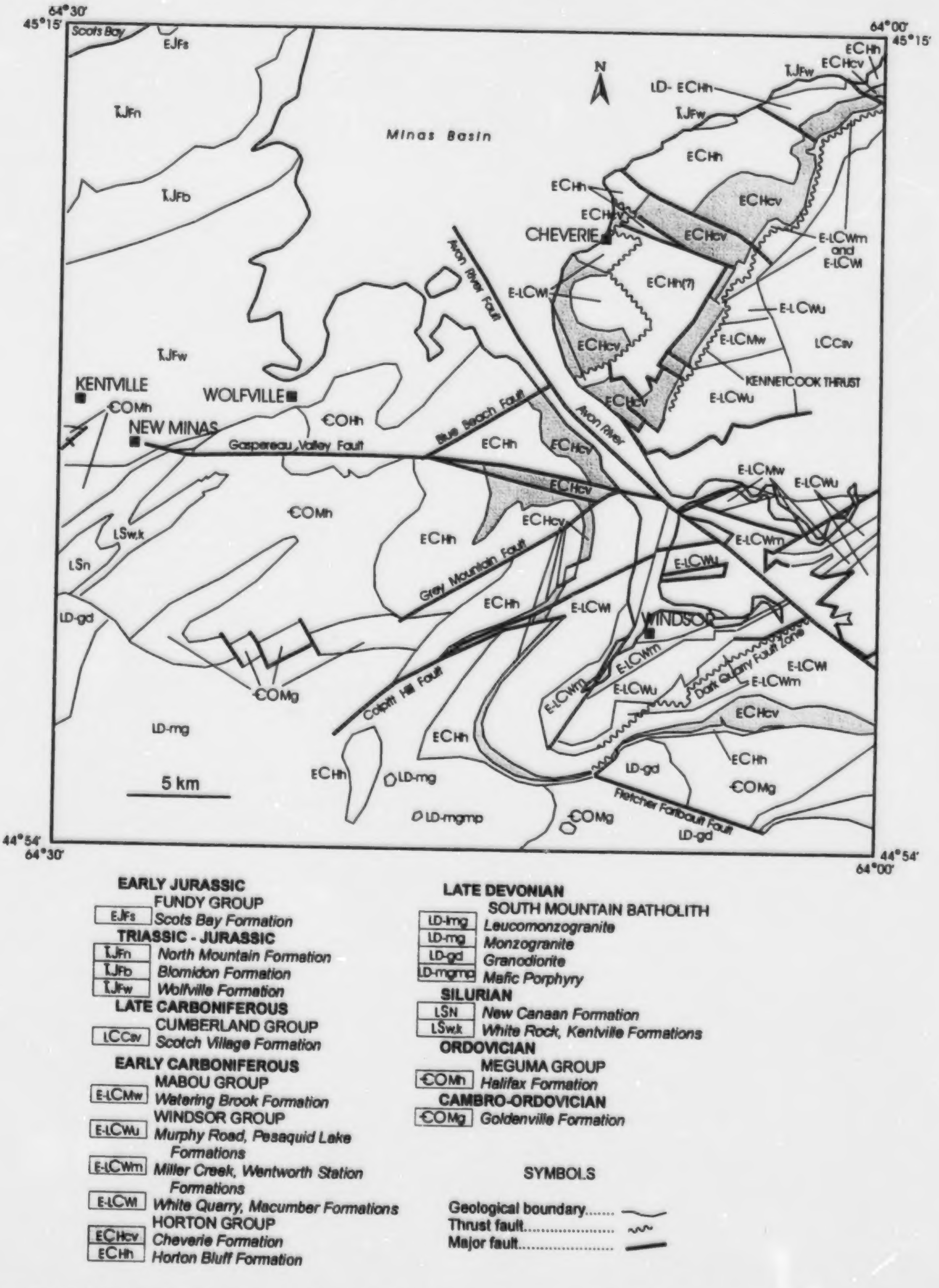

Figure 2. Simplified geological map of the Wolfville - Windsor map area, including the western part of the Windsor Basin.

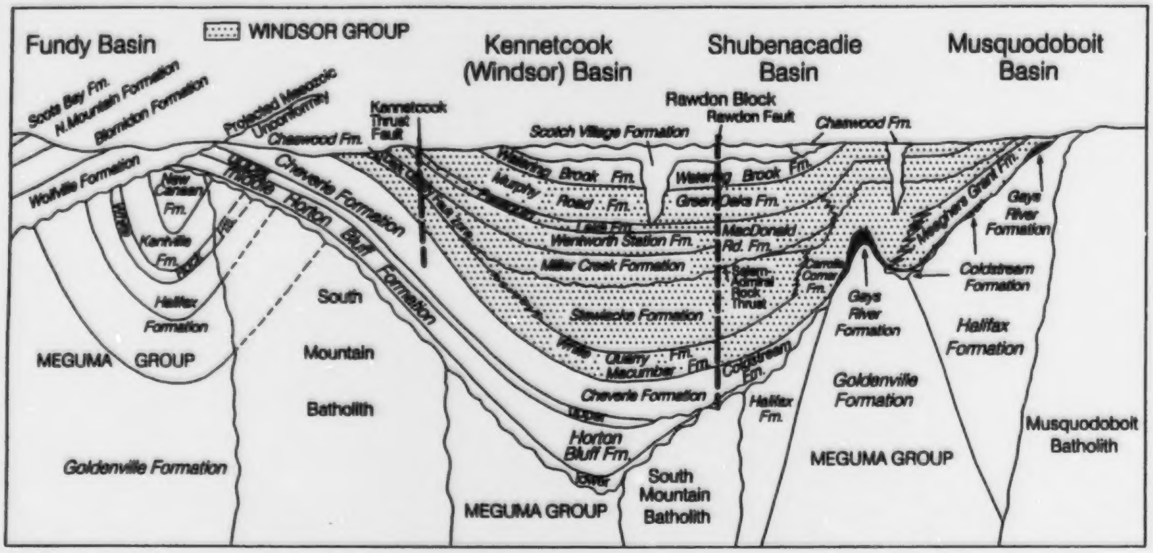

Figure 3. Highly simplified diagrammatic representation of geological map units in the Wolfville - Windsor map area.

grained alluvial strata of the Horton Bluff and Cheverie formations of the predominantly Tournaisian -Viséan age Horton Group (rare Late Devonian). The Horton Group is sourced from and onlaps the basement metasedimentary and granitoid rocks along parts of the southern and western borders of the Windsor Basin. The Viséan Windsor Group disconformably overlies the Horton Group and comprises an interstratified sequence (up to 800 m) of marine evaporites, carbonates and continental redbeds. The Windsor Group and part of the Horton Group contain numerous industrial mineral occurrences, including barite, gypsum, anhydrite, salt, dolomite and limestone, as well as base metals including Pb, Zn and Cu, Mn, and locally Ag and U.

The Watering Brook Formation of the Mabou (Canso) Group generally conformably (local disconformities) overlies the Windsor Group and comprises up to 150 m of late Viséan grey and red mudrocks, gypsum, anhydrite and locally halite. Basin fill of the Horton, Windsor and Mabou groups is unconformably overlain by the Namurian-Westphalian Scotch Village Formation. The Scotch Village Formation has previously been included as part of the Pictou Group, but is now re-assigned to the Cumberland Group. It comprises more than 300 m of fluvial grey sandstone and red mudrocks in the central area of the basin, and regionally overlies an eroded landscape of variably deformed Windsor and Mabou group strata.

Stratigraphy and Depositional History

The stratigraphic succession within the Windsor Basin is similar to that occurring in many of the late Paleozoic basins in Nova Scotia and has elements of both evaporitic marine and nonmarine deposition. The initial basin-fill of the Horton Group (Fig. 3) comprises a three part succession of upper and lower coarse-grained facies and a medial fine-grained facies. In general, the coarse-grained facies are primarily fluvial and alluvial deposits of the lower and uppermost parts of the Horton Bluff Formation (lower and upper units on Fig. 3), and the Cheverie Formation. The fine facies constitute the middle part of the Horton Bluff Formation and are dominated by lacustrine deposits (including carbonates).

The Horton Bluff Formation is approximately 350-525 m thick in the type area and may exceed 1000 m in the central part of the basin. It generally displays fining upward and basinward trends. The Horton Bluff Formation is overlain conformably (and locally disconformably) by the coarse-grained Cheverie Formation, which is approximately 100-260 m thick in the type area. The coarse alluvial fan facies, including red and green conglomerate, form part of the Coldstream Formation (50-90 m thick) in the Shubenacadie Basin near the southeasterly pinchout limits of the Horton

Group on the Meguma Platform. These conglomeratic facies are not well represented in the Windsor Basin, except locally along the southern and southeastern border of the basin adjacent to the Rawdon Fault zone. Very little is known about the thickness, stratigraphy and lithology of the Horton Group in most of the west-central part of the Windsor Basin.

The continental alluvial fluvial-lacustrine sedimentation phase of basin development was suddenly succeeded by a regional marine invasion of the Windsor seas in the early Viséan. Catastrophic flooding of a sub-sealevel basin landscape with nearly instantaneous transgression is inferred. Locally, for example in the Cheverie area, there is a thin, sparsely fossiliferous quartzose sandstone associated with the transgression at the contact between the Cheverie and Macumber formations. This marine sandstone is included in the basal part of the Windsor Group. The basal unit of the Windsor Group is a marine carbonate which occurs regionally in several distinctive facies. The dominant facies is the Macumber Formation, which comprises laminated limestone 1-17 m thick. It is generally present in outcrop in the northern part of the basin (its type area) and is inferred to extend throughout much of the subsurface of the basin (Figs. 1, 2, 3). The correlative buildup (biohermal) facies is called the Gays River Formation, which ranges in thickness from 15-30 m and has limited areal extent. It is not known to be developed in the Windsor Basin, but is well represented in the type area in the southern part of the Shubenacadie Basin and in much of the Musquodoboit Basin. The Gays River Formation buildups are generally developed on pre-Carboniferous basement rock beyond the Horton Group pinchout (e.g. Shubenacadie Basin, Fig. 3). Buildups were particularly well developed on or around basement topographic highs within and peripheral to the depositional basin margins. Suitable basement highs may not have been present or carbonate buildups not preserved in the present day erosional limits of the Windsor Basin.

The typical anhydrite- and salt-dominated evaporite sequence of the lowermost Windsor Group is well represented in the area. Although there are no complete basinal sections through the White Quarry (Carrolls Corner Formation correlative) and Stewiacke formations, these units together are typically up to 400 m thick. They are inferred to extend throughout the basin, but the present distribution of saline evaporites of the Stewiacke Formation is limited by structure and subsurface dissolution.

Strata typical of the middle part of the Windsor Group (B Subzone of Bell, 1929) are included in the Miller Creek, Wentworth Station, and Pesaquid Lake formations, which have a total thickness of approximately 120 m. Due to the extensive deformation in their type areas near Windsor, the contacts between these units are generally faults. The upper contact of the Pesaquid Lake Formation with the Murphy Road Formation is conformable. These units are characterized by a major change in depositional style and are distinctive in comprising numerous thinner transgressive and regressive cycles (minicycles) of marine carbonates, evaporites and redbeds. Regionally, this represents repeated marine transgression and regression, individually recorded by fossiliferous marine carbonate, overlain by progressively saline marine evaporites (anhydrite and salt) and capped by continental redbed siliciclastics. The Miller Creek, Wentworth Station and Pesaquid Lake formations are distinctive in their constituent carbonate members and correlate with the MacDonald Road Formation in the adjoining Shubenacadie Basin and Musquodoboit Basin. The absence of coarse- grained siliciclastics and no apparent onlap of basement rocks indicates that the marine invasions in the Windsor Basin were similar to those in the Shubenacadie and Musquodoboit basins: they occurred over a terrain with very subdued paleotopographic relief, and were accompanied during regressions by input of fine-grained siliciclastics.

Carbonate rocks of the Miller Creek, Wentworth Station and Pesaquid Lake formations are typically shallow water deposits, ranging from intertidal/supratidal to subtidal below wave base environments. They include algal stromatolites, oncolitic and argillaceous micritic packstone, wackestone and mudstone (rarely oolitic), with variable shelly biota of brachiopods, gastropods and bivalves. The nodular sulphate and fine redbeds represent regressions with the development of sabkha-type hypersaline mudflats and the massive mosaic anhydrite and stratified salt deposited on hypersaline lagoonal (subaqueous) evaporites in basinward sections.

The Miller Creek, Wentworth Station and Pesaquid Lake formations are overlain by a lithologically similar package of interstratified red siltstone, marine carbonate and minor evaporite comprising the Murphy Road Formation. The Murphy Road Formation constitutes the upper part of the Windsor Group (Subzones C, D and E of Bell, 1929) and is approximately 185-200 m thick. The lower contact is conformable with the underlying Pesaquid Lake Formation. The Murphy Road Formation is the uppermost formation of the Windsor Group and records the last marine carbonate deposition in the area. With the exception of the variation in lithologic component proportion (e.g. an overall decreased evaporite and greater redbed content) the depositional environment for the carbonates, sulphate evaporites and redbeds is generally similar to that described for the underlying Miller Creek, Wentworth Station and Pesaquid Lake formations. The Murphy Road Formation correlates with the Green Oaks Formation in the adjoining Shubenacadie Basin and the Musquodoboit Basin (Figs. 1 and 3).

The Watering Brook Formation of the Mabou Group comprises grey and red mudrocks, gypsum, anhydrite and locally halite. It is approximately130 m or more in thickness and conformably overlies the Murphy Road Formation at the top of the Windsor Group in the Windsor Basin. These deposits represent the transitional return to continental (initially saline) lacustrine and fluvial deposition with the retreat of the Windsor seas. Evaporite deposits present in this interval indicate a residual connection to the parent marine environment.

Overall, paleotopography and tectonism appear to have had a diminishing influence on sedimentation in the Lower Carboniferous comprising the Horton, Windsor and Mabou groups in the Windsor Basin. The importance and influence of topography decreased with time, as erosion and successive deposition of onlapping strata buried the basement relief within and around the perimeter of the Windsor Basin. The depositional sequence to the top of the Mabou Group (late Viséan) displays a general pattern of fining upwards. Regional uplift to the north of the basin, near the end of deposition of the Miller Creek, Wentworth Station and Pesaquid Lake formations (B Subzone), probably significantly restricted the areal extent of marine deposition to the north.

Windsor and Mabou group strata in the Windsor Basin are unconformably overlain by a sequence of interstratified fine- to medium-grained, grey sandstone and red to grey mudrocks assigned to the Scotch Village Formation. These strata are known to exceed 300 m in thickness and occur throughout the Windsor Basin and parts of the adjacent Shubenacadie Basin (Figs 1, 2 and 3). The stratigraphy, age and contact relationships of rocks included in the Scotch Village Formation initially appeared simple; however, further palynological work indicates they are complicated. The Scotch Village Formation was formerly understood to be dominantly mid- to late-Westphalian in age, but it includes a substantial section of Namurian strata. Further seismic surveys and drilling will be required to clarify this because these strata have very limited subsurface data and very poor outcrop representation. The major unconformable contact with the underlying early Carboniferous basin fill is locally revealed by significant erosion and reworking, including the inclusion of upper Windsor Group marine fossil detritus in the Scotch Village Formation. For example, the unconformable contact of the Scotch Village Formation with the lower part of the Green Oaks (Murphy Road) Formation at Riverside Corner (e.g. drillhole NSDME RC85-1; Boehner, 1994), near the southeastern border of the Windsor Basin (Fig. 1), indicates the locally substantial erosion of Lower Carboniferous strata. The braided fluvial mudflat strata of the unconformably overlying Scotch Village Formation record a substantial change in the sedimentation pattern in the Windsor Basin and adjacent Shubenacadie Basin. This follows the general pattern in the regional Maritimes Basin, especially in the late Namurian to Westphalian, with the return to sustained fluvial and alluvial deposition typical of the Late Carboniferous.

Carboniferous basin fill on the northern boundary of the Windsor Basin is proximal to the regional Cobequid-Chedabucto Fault System and is variably to intensely deformed (Fig. 1). These rocks comprise the Walton Block and are unconformably overlain by the southern outcrop margins of the Mesozoic rift basin fill. The basal units are represented by Late Triassic, medium-grained, redbed siliciclastics of the Fundy Group (Wolfville Formation). Carbonate breccias of tectonic and karst origin (multigeneration?) are commonly associated with the Macumber Formation outcrops in this area. These rocks are referred to as Pembroke breccia and are part of the host for base metal and barite mineralization.

Remnants of early Cretaceous silica sand and clay are locally present on top of the Carboniferous rocks (Fig. 3); however, their stratigraphy and distribution in the Windsor Basin are poorly known. These unconsolidated Cretaceous deposits are probably correlative with the Chaswood Formation in the adjoining Shubenacadie and Musquodoboit basins. Recent mapping, drilling and seismic surveys have significantly expanded the known distribution, detailed stratigraphy and structure. Faults locally offset both the Cretaceous and Carboniferous strata. Small Cretaceous occurrences have also been reported in the southern part of the Windsor Basin near McKay Section and in the Fundy Gypsum Miller Creek Quarry (Fig. 1). A thick section of unconsolidated sand (potentially Cretaceous) was recently intersected in mineral exploration drilling to a depth of 150 m at Wade Lake near Goshen (Fig. 1) in the northwestern part of the basin.

Mafic sills and dykes associated with periods of intrusive and extrusive activities occur throughout the geological column in the Wolfville - Windsor map area.

In the post-Cambrian to Silurian, mafic dykes and sills intruded Halifax Formation rocks and locally, post-Halifax Formation strata. Within the Windsor Basin, mafic dykes and sills locally intruded Early Carboniferous Horton Group strata. The Horton Bluff Formation has small, intensely altered mafic dyke and sill intrusions at Johnson Cove near Cheverie where there are six localities at three stratigraphic levels. Similar intrusions occur near Cheverie (New Cheverie Road) and Grey Mountain.

Structure

The Windsor Basin is the most structurally disturbed of the Carboniferous overstep basins in the Meguma Zone. This is primarily due to its proximity to the regional Cobequid-Chedabucto Fault System (CCFS), as well as the related Mesozoic Fundy Basin (Figs. 1, 2 and 3). The Windsor Basin has the basic configuration of a synclinorium with northeastward- to eastward-trending synclines and anticlines. The basin is truncated on the southeast by the Rawdon Hills Block and Rawdon Fault, on the northwest in the Walton Block by the onlap unconformity of the early Mesozoic Fundy Basin, and on the west by the onlap unconformity of the Meguma (Zone) Platform. The extension and continuity of basin rocks beneath the Mesozoic Fundy Basin (mainly submerged beneath the Minas Basin) to the north is not defined in drilling or seismic surveys. Fault blocks of Lower Carboniferous rocks in the complex CCFS along the northern shore of the Minas Basin, however, are geologically similar to rock units exposed in the Windsor - Wolfville map area (e.g. outcrops of Murphy Road, White Quarry and Macumber formations).

Complex structure pervades the middle part of the Windsor Group and parts of the Horton Group (e.g. Horton Bluff Formation in the Walton Block) including recumbent folding related to the thrust and decollement. Substantial dip-slip (and potentially strike-slip) movement, postdating the Windsor Group, is indicated on these faults. The movement history includes episodes that postdate the Westphalian B-C and postdate the Early Cretaceous. There are numerous minor and major folds in the basin, including the Walton, Melanson Mountain and Grey Mountain anticlines. These folds are defined primarily by Lower Carboniferous strata. The folds are generally open and asymmetric, with gentle and steep to locally overturned dips near the faults.

The dominant structural features of the western part of the Windsor Basin are prominent northeastward- and northwestward-trending faults including the Rawdon, Avon River, Pesaquid Lake and Kennetcook Thrust faults. The Rawdon Fault is a high-angle reverse fault clearly related to the underlying basement rocks and probably extends through the Meguma Group and South Mountain Batholith basement to the southwest. The Kennetcook Thrust is a complicated fault zone along the northwestern border of the basin. In this area, Horton Group and locally lowermost Windsor Group strata (Macumber and White Quarry formations) occur as a steep to overturned southern limb to the major Walton Anticline structure which dominates much of the structurally complicated Walton Block. These units are typically juxtaposed with upper Windsor (e.g. Murphy Road Formation) or younger Carboniferous units to the south and east in the basin. This includes the locally very complicated folding and faulting as well as thrust movement at different scales within the Horton and Windsor groups.

Seismic surveys in the east-central part of the basin have been interpreted to indicate southerly directed thrust movement of the Walton Block over the Windsor Basin rocks to the south. The magnitude and depth of the inferred thrust, both towards the north and south, are unknown. Complex, recumbent isoclinal folds in the Wentworth Station and Miller Creek formations and in the Dark Quarry Fault Zone near Windsor are known to occur in other parts of the basin and may extend as a basinwide decollement zone. A genetic connection to the Kennetcook Thrust is also possible. Further seismic surveys and drilling will be required to clarify the geology and structure of the central and deep basin areas.

The Kennetcook Thrust and Rawdon Fault are part of an extensive northeastward-trending fault system extending from the Meguma Zone into the east-west Cobequid-Chedabucto Fault Zone, which extends through central Nova Scotia from the Bay of Fundy to Chedabucto Bay and offshore. The Avon River and Pesaquid Lake faults appear to be primarily related to strata above a decollement (related to the Kennetcook Thrust?) at the top of the White Quarry Formation (and within the Stewiacke Formation). Regional magnetic field patterns are defined by the typical higher magnetic response of the Halifax Formation and lower response of the Goldenville Formation in regional scale northeastward-trending folds. This pattern can be traced from the outcrop areas beyond the basin into the basin (with attenuation due to the basin fill). Significant strike-slip offsets (1 km or more) of the Avon River or Pesaquid Lake faults are not evident in the western part of the basin.

The present basin configuration reflects a two-part structural system with local block faulting, foldingtilting and erosion of the Mabou Group and older rocks, followed by deposition of the Namurian to Westphalian Scotch Village Formation above the unconformity. Local faulting, such as along the Rawdon Fault, has disturbed the Scotch Village Formation, indicating a movement event after the Westphalian B-C. Subsequently, there was structural disturbance, including faulting, associated with the Late Triassic. In addition, there may have been post-Early Cretaceous faulting and folding similar to that evident in the Chaswood Formation of the Musquodoboit Basin. The structural history of the basin is locally very complex, due in part to the proximity to the regional Cobequid-Chedabucto Fault System. Tectonism occurred throughout the development of the Carboniferous and Mesozoic basin fills, especially during the late Namurian to early Westphalian, post-Westphalian, and post-Triassic.

There is a close paleogeographic relationship between the Musquodoboit, Shubenacadie and Windsor (Kennetcook) basins. These structural basins appear to have only modest dislocation and disruption on the northeastward-trending faults linked to the Cobequid-Chedabucto Fault System to the north. The general and detailed stratigraphy, structure and facies patterns are very similar, indicating close spatial and temporal relations throughout their history.

Mineral Resources and Mining

Mining activity in the western part of the Windsor Basin has concentrated on the extensive industrial mineral resources over the past 200 years. Limited, but economically significant, mining of base metals and silver occurred at the Walton deposit. Mineral exploration has historically focused on base metals and barite in the basal Windsor Group (e.g. Walton, Gays River, Smithfield, Upper Brookfield, Fig. 1) as well as industrial minerals including sulphur, salt, potash and gypsum in the Windsor Group. A special issue of the journal *Economic Geology* was published recently (see Sangster and Savard, 1998, for current papers and contained references) which documented the geology of base metal mineralization in the Carboniferous basins of Nova Scotia. Significant lode gold was produced from deposits in the Meguma Group in the Rawdon Hills area and minor placer gold has been recovered from surficial drainage basins. The Walton barite deposit was a major carbonate-hosted barite and base metal/silver deposit discovered in the 1950s and in production until the 1970s. Substantial mining problems related to weakly consolidated host rocks, fracturing and water influx were encountered and continued throughout the life of the mine.

Gypsum mining has been continuously active in the Windsor Basin for over 200 years. Gypsum and anhydrite occur in extensive deposits in the area. Early production was characterized by a large number of small, independent producers. Larger operations were rare in the early history; however, this evolved in more recent times with the consolidation of deposits and production by large producers. Major production has occurred for more than 40 years at the Miller Creek and Wentworth quarries operated by Fundy Gypsum Company. A smaller gypsum quarry near McKay Section and a gypsum products plant in Windsor were recently closed by Domtar after many years of operation. Recently there has been substantial (multi-million dollar) investment by Fundy Gypsum to upgrade their production and processing operations at Wentworth and Miller Creek. Limestone has also been produced locally on a limited basis for agricultural applications.

The Windsor Basin has been extensively explored for base metal and barite deposits. This exploration is, in part, related to the discovery and development of the Walton barite deposit and the subsequent discovery of a significant base metal sulphide and silver ore body in its lower part. Exploration has focused primarily on the Horton Group- Windsor Group contact, especially the prospective basal carbonates of the Windsor Group. This exploration activity stimulated the discovery of significant tonnages of these metals at Gays River, as well as other similar prospects. In addition to base metal and barite deposits, exploration has been undertaken in several less intensive phases for celestite, sulphur, salt, potash and uranium.

Petroleum exploration drilling was undertaken in the Cheverie, Falmouth and Kennetcook areas in several exploration plays beginning in the early 1900s. Exploration interest continues in the region as a result of hydrocarbon shows and favourable geology. Most of this hydrocarbon exploration has focused on plays in the Horton Group and the lowermost part of the Windsor Group because of potential reservoirs in the Horton and evaporite seals in the Windsor.

Metallic Minerals

Exploration for base metals in the Windsor Basin has focused on the Horton-Windsor contact zone, especially the basal carbonate of the Windsor Group. One of the most prospective exploration areas is in the Walton Block, extending along the northern border of the basin, especially between the Avon River and Upper

Brookfield. The numerous Pb, Zn, Cu, Mn, Ag (trace Co, Ni) mineral occurrences and prospects in the area commonly occur where the basal carbonate (Macumber Formation) overlies Horton Group continental siliciclastics (e.g. Walton, Upper Brookfield, Smithfield). Mineral deposits are also associated with basal carbonate buildups on Meguma Group basement beyond the Horton Group pinchout (Gays River Formation at Gays River). The Windsor Group basal carbonate and base metal-silver mineral association has been long recognized and investigated. Barite and siderite are commonly associated with these base metal deposits and in some cases are the dominant economic minerals.

Carbonate buildups of the Gays River Formation at the base of the Windsor Group are major exploration targets as potential hosts for base metal deposits of the Gays River Zn-Pb type. Many of these were discovered and explored throughout the 1970s, and although the host buildups are locally well developed, only a few were significantly mineralized. Although these buildups are not known to be present in the basin margin areas, they may occur in the deeper, unexplored parts of the Windsor Basin.

Significant lode gold was produced from various fold related quartz vein deposits in the Meguma Group in the Rawdon Hills. Minor placer gold has been prospected and recovered from surficial drainage basins in the southern part of the Windsor Basin. This gold is inferred to have originated locally from lode gold mineralization in the underlying Meguma Group. Similar potential exists for paleoplacer deposits associated with the lower part of the Horton Group because it has a substantial source area in the surrounding Meguma Group metasedimentary rocks.

Non-metallic (Industrial) Minerals

Barite-Siderite

Discordant, stratiform and stratabound barite deposits, with or without associated siderite, base metals and silver, are well documented in the Windsor Group in the Windsor Basin and in the adjacent Shubenacadie Basin. The structurally controlled barite and siderite mineralization occurs primarily in association with faulted Macumber Formation and related Pembroke breccia carbonates along the structurally complicated Walton Block on the northern side of the Windsor Basin (e.g. Lower Burlington, Cheverie, Walton and Goshen). This mineral zone extends eastward into the northern side of the Shubenacadie Basin and includes the high-grade barite at Upper Brookfield (Nystone - Division of E-Z-EM Canada Inc., producer of high-grade medical barite) and occurrences at Middle Stewiacke, Southvale and Hilden.

Limestone and Dolostone

Limestone and dolomite occur throughout the Windsor Basin and are described in a report by Murray and Luke (in prep.). The most important occurrences of high quality limestone are located within the Windsor Group including, for example, small biohermal buildups associated with certain carbonate members of the MacDonald Road Formation. There has been minor previous production from carbonates of this type in the Windsor area. There are also known occurrences near Avondale and in the Miller Creek Quarry. There is currently no significant production at these locations.

Gypsum and Anhydrite

Gypsum and anhydrite outcrops are very widespread in the Windsor Basin area and the nature of these deposits is closely related to the stratigraphy, structural history, erosion and exposure to groundwater. The evaporitic sections dominating the Wentworth Station and Miller Creek formations and the underlying White Quarry (Carrolls Corner) and Stewiacke formations have undergone (and continue to) varying degrees of dissolution in the near-surface and subsurface environments. Karstification features, including dolines, hummocky topography, sinkholes, cavities and other solution structures, are locally well developed in the near-surface environment. The penetration of groundwater has dissolved at least some and probably much of the periphery of the Stewiacke Formation salt in the Windsor Basin. Salt springs are locally very abundant. This dissolution process, together with accompanying hydration of most parts of the disturbed Wentworth Station and Miller Creek formations and the upper part of the White Quarry Formation, has produced very large gypsum deposits in the area.

There are very thick economic sections of gypsum (60 m or more) associated with extensively hydrated zones of the Windsor Group evaporite section. Historically, gypsum exploration, development and mining occurs near the contact between, and within, the White Quarry Formation (the A Subzone, basal anhydrite) and the overlying Wentworth Station and Miller Creek formations (B Subzone). This geology occurs extensively along the southern border of the Windsor Basin near Windsor, as well as near Cheverie and Walton along the northern border of the map area. The White Quarry Formation is generally less structurally disturbed than the overlying Wentworth

Station and Miller Creek formations, which are typically isoclinally/recumbantly folded and faulted. These units, in their type areas in the Fundy Gypsum Company quarries along the southern border of the basin, are separated by a structurally disturbed contact zone (the Dark Quarry Fault Zone) near the top of the White Quarry Formation. Regionally, a major stratigraphic unit named the Stewiacke Formation occurs at this position. It is very distinctive, known only in subsurface sections and dominated by stratified halite with subordinate anhydrite and mudrock. Near-surface dissolution processes have invariably removed the soluble evaporites from these sections, especially near permeable fault zones and basin margins. Stratified halite is known to occur in correlative sections of the Wentworth Station and Miller Creek formations (B Subzone) in the eastern part of the basin near Riverside Corner and Upper Walton River. The presence of halite has a potentially major role in the structural discontinuity, complex folding and faulting at the top of the White Quarry Formation, both locally and regionally (major decollement zone).

These units and the structurally disturbed contact zone have the greatest potential for gypsum development due to the balance of appropriate rock types, stratigraphy and structure. Fractures, natural rock permeability and associated groundwater penetration are essential to fully hydrate the parent anhydrite beds. This situation has been identified both locally and regionally (e.g. Musquodoboit and Shubenacadie basins) where exceptionally thick and extensive hydration occurs. A contributory component (locally dominant) is an association of gypsum with residual material from the dissolution of a major stratified salt unit (with subordinate anhydrite interbeds) in the Stewiacke Formation, which occurs (formerly occurred) at this exact stratigraphic level.

Salt and Potash

The first exploration for potash deposits in the Windsor Basin was undertaken in 1974, as a consequence of the previous discovery of large potash deposits associated with gravity anomalies in the lower part of the Windsor Group in New Brunswick. Exploration drilling was carried out on the large Kennetcook gravity anomaly at Clarksville (near Riverside Corner, Fig. 1) along the southeastern border of the basin immediately east of the Wolfville-Windsor map area. This drilling encountered deformed stratified salt deposits in the Watering Brook Formation above the Windsor Group. Although potash salts were not intersected, substantial salt deposits are documented here and throughout the Windsor Basin (eight deposits and occurrences), as well as in the adjacent Shubenacadie Basin. Deep petroleum exploration wells and mineral exploration drillholes intersecting significant salt sections include: Anthony No. 1 near Kennetcook, Noel No. 1 near Noel Road, and Riverside Corner RC 85-1 near Riverside Corner (Boehner, 1994). The Windsor Basin has numerous occurrences of salt springs and seeps, indicating the wide distribution of salt-bearing Windsor Group rocks. There is significant potential for large, stratified salt resources and potentially potash in the central region of the basin.

Native Sulphur

The occurrence of native sulphur in the Windsor Group has been investigated since the 1960s. The Hilden area, located at the far eastern extremity of the Windsor Basin (Fig. 1), has interesting occurrences of native sulphur both in outcrop and in exploration drill core. The sulphur occurs with calcite, fluorite and trace hydrocarbons in fracture-fill within evaporites of the lower part of the Windsor Group (Carrolls Corner Formation). It is interesting to note that there is an unusual anhydrite/fluorite vein association without sulphur in the White Quarry Formation (Carrolls Corner Formation correlative) anhydrite at White Head near Cheverie. Hydrocarbon occurrences are abundant in the Windsor Group at this locality. The association of native sulphur and hydrocarbons is a well known connection in commercial developments.

Petroleum and Natural Gas

Interest in hydrocarbon exploration (including exploration well drilling) began in the early 1900s near Cheverie and Falmouth (Windsor). Drilling and seismic programs have operated from the mid 1940s (e.g. Kennetcook) to the early 1980s (e.g. Noel), with several wells drilled in the Kennetcook area. Most of this hydrocarbon exploration focused on plays in the Horton Group and the lowermost part of the Windsor Group. The prospective rocks in this interval are noted for hydrocarbon shows and occurrences (e.g. Cheverie, Walton Barite Mine, Soquip *et al.* Noel No. 1 etc.); however, commercial discovery and development has yet to occur. In the adjacent Shubenacadie Basin, drillhole NSDME Alton 87-1 intersected a high pressure flow of natural gas (methane) near the top of the Carrolls Corner Formation anhydrite where it is overlain by salt of the Stewiacke Formation. Small gas seeps and gas shows are frequently associated with mineral exploration diamond-drill holes intersecting Windsor Group evaporites. Minor natural gas occurrences were detected in the Soquip *et al.* Noel No. 1 well and oil seeps were common in mine workings intersecting the Windsor

Group. Outcrops of evaporite and carbonate rocks are locally very petroliferous, especially the White Quarry Formation anhydrite near Cheverie in the northwestern part of the Windsor Basin. Liquid hydrocarbon was a commonly encountered in the underground workings of the Walton barite mine and is often associated with the ore zones. The potential for hydrocarbon resources in the deeper parts of the Windsor Basin and adjacent Shubenacadie and Musquodoboit basins is virtually unknown at this time because the lack of geological information. This hydrocarbon potential requires additional exploration and drilling for assessment.

Coal

Minor, fissile coaly shales occur in association with the Scotch Village Formation in the Windsor and Shubenacadie basins. Similar centimetre-scale coaly shales have been intersected in drillholes in the Windsor Basin, but do not appear to be of economic significance.

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Paleozoic Basin Research

J. H. Calder

Introduction

The component basin-fill rocks of the Maritimes Basin complex, although predominantly of Carboniferous age, span the mid-Devonian through lower Permian (Calder, 1998). Historically, work has focused on coal resources of Carboniferous age within this succession, but insight into these resources, as well as related hydrocarbons and non-traditional resources, requires research encompassing several disciplines, both related and disparate. Current investigations include Late Carboniferous biostratigraphy, coal geochemistry, paleontology of the Joggins Formation and Devono-Carboniferous hydrocarbon source rocks. Progress on these topics is reported here.

The exchange of critical ideas with international colleagues that is fundamental to such research was assisted in 1999 by hosting the pre-meeting field trip (Calder *et al.*, 1999) of the XIV International Congress of the Carboniferous and Permian (Calgary), last held in North America in 1979. Such co-operation provides invaluable scientific resources which otherwise would be unavailable or prohibitive in cost.

Biostratigraphy

The accepted geological age assigned to complex lithostratigraphic units comprising the Paleozoic sedimentary basin fill has a profound impact on models of basin evolution and the mineral, energy and paleontological resources in the component basins. In the virtual absence of absolute, radiometric dates, the relative ages provided by biostratigraphy are of key importance. Progress in three key localities of the Maritimes Basin is reported below.

Joggins, Cumberland Basin (NTS 21H/09)

The Joggins section is one of the most important Carboniferous sections in the world and is of strategic importance in interpreting the history of the Maritimes Basin, which in turn links the geological history of northeastern North America and western Europe (Calder, 1998). Long held to be of early Westphalian age (Bell, 1944; Hacquebard and Donaldson, 1964; Dolby, 1991), the age of the coal-bearing Joggins Formation has recently been investigated and called into doubt (Utting and Giles, 1998), with assertions that the section may be entirely pre-Westphalian. If this conclusion is correct, it will have profound implications on the interpretation of Maritimes Basin history and stratigraphy.

The Namurian-Westphalian boundary is defined in the western European Carboniferous Basin primarily on the basis of the *Gastrioceras subcrenatum* marine band, an open marine goniatite fauna which is not present in the Maritimes Basin. In the terrestrial realm, few plant extinctions or appearances occur across this boundary, which makes its resolution extremely difficult in the absence of the defining marine record. In the Maritimes Basin, this challenge is heightened by the virtual absence of one of the most useful plant groups that make a marked appearance in the Westphalian, this being the densospore-producing group of lycopsids. Their paucity in the Maritimes Basin has been attributed to unfavourable ecological conditions, supported by the interpretation from the rocks of a more seasonally stressed climate in the Maritimes than in Western Europe and the Appalachian and Interior basins of the United States (Calder, 1991, 1998).

Controversy about the age of this classic section has resulted in considerable attention to the floral record by palynologists and macrofloal paleobotanists. It is apparent that the classic coal-bearing section, the Joggins Formation, lies close to the Namurian-Westphalian boundary or transition, with elements of both late Namurian and early Westphalian floras. Current research suggests that it is, at youngest, early Westphalian 'A' (Langsettian) and may in fact span the boundary.

A re-evaluation of key specimens representative of the Cumberland Group (*sensu* Ryan *et al.*, 1991) from the macroflora collections of W. A. Bell at the Geological Survey of Canada was undertaken by R. H. Wagner, Córdoba, Spain, who concluded in his report to the Geological Survey of Canada that the flora are representative of the Westphalian A-B (Wagner, 1999). Joint examination of the section by Dr. Wagner and the author during the pre-meeting field trip of the XIV International Congress of the Carboniferous and Permian in Calgary, however, yielded earlier taxa evocative of the late Namurian, such as *Neuralethopteris larischii* (provisional) which will be studied further.

Systematic identification of macroflora within a stratigraphic context will help to constrain the age of the section as the only major biostratigraphic data set available to complement and test palynological results. Detailed paleo-ecological studies of parts of the section undertaken earlier by the author (Calder *et al.*, 1999, and in preparation) provide important data in this regard. It will be particularly important to constrain the upper age range of the section, represented by strata at Spicer Cove at the far southern limit of the coastal section. Here, a diverse macrofloral assemblage awaits collection and further study.

The age of rocks below the Joggins Formation are being revised currently by palynologists J. Utting and G. Dolby and their results are being prepared for publication by the Geological Survey of Canada. In general, their current research suggests that the ages represented in descending order by the Boss Point, Claremont and Shepody formations are older than previously recognized. A possible hiatus between the Boss Point Formation and underlying Claremont Formation would lend support to exclusion of the Claremont from the Cumberland Group as presently defined (Ryan *et al.*, 1991). The implied disconformity corresponds to the mid-Carboniferous Break, which has been described as the most profound event recorded in the geological evolution of Carboniferous fill in the Maritimes Basin (Calder, 1998).

Resolution of the age of the lower Carboniferous Shepody Formation has major implications for global magnetostratigraphy, as the redbeds of this unit have been used to define a global magnetic polarity reversal (DiVenere and Opdyke, 1991, and others) that is widely used to constrain the lower Carboniferous time scale (M. Menning, personal and written communication, 1999) and paleocontinental reconstruction (Scotese and McKerrow, 1990, and others).

Brule, Cumberland Basin (NTS 11E/14)

The Brule walchian forest and tetrapod trackway site provides a data set that helps to constrain the age of the problematic redbeds, specifically the Cape John Formation of the Pictou Group, that constitute the uppermost fill of the Cumberland Basin in northern Nova Scotia. Compression fossils of the walchian conifers, evocative of the *Auracaria* such as Norfolk Island pine, are typical of lower Permian redbed localities in paleotropical North America and Europe, but their occurrence has been reported from older strata. The conundrum of diachronous appearances of the walchian conifers in response to different timing of the onset of increasing aridity in the late Carboniferous and early Permian remains a concern in their biostratigraphic utility. The temnospondyl-cotylosaur-pelycosaur ichnotaxa represented at Brule is consistent with the Lower Rotliegend of Europe and lower Wolfcampian of southwestern USA, although similar concerns of earlier, ecologically controlled appearances in the Maritimes Basin apply to the vertebrate record as well. Ecological influences not withstanding, the weight of paleontological evidence at Brule is consistent with a post- Stephanian age, within the lower or more probably middle Autunian (R. H. Wagner, written communication, 1999).

Spring Valley 1 Well, Prince Edward Island

The macrofloral record of the 1706 m succession cored in the Spring Valley 1 well was assessed at the request of industry in order to help constrain stratigraphic interpretation in the subsurface of this portion of the Maritimes Basin, for which little biostratigraphic data exist. Interpretation of the basin fill on Prince Edward Island provides an important constraint to geological interpretations of the geology of northern Nova Scotia. The age of the cored sequence, which was sampled with the assistance of Lyndon Jensen under contract to the P. E. I Gas Co. Ltd., can be constrained provisionally from near total depth of the well to within 800 m of surface, above which the redbeds are barren of macroflora.

Strata near the base of the well at 1646.59 m yielded an uncommon flora provisionally identified as *Palmopteris furcata*. This taxon has been reported from the Westphalian B (Duckmantian) of Britain (Cleal and Thomas, 1994) but its range is not well constrained (R. H. Wagner, personal communication, 1999). It is possible that strata at the base of the Spring Valley well may be considerably older than Westphalian B, given the simple, primitive structure of this enigmatic fern-like foliage. A rich assemblage in a dark grey interval from 1079-1080 m, dominated by *Neuropteris sp.* with *Cyperites sp.*, less common *Lobatopteris*, and rare *? Mariopteris* and *?Eusphenopteris spp.*, is no younger than Stephanian nor older than Westphalian D. This assemblage in particular, and macroflora generally from 893 to 1216 m depth, are evocative of the Sydney Mines Formation of the Sydney Basin, which ranges in age from Westphalian C to Cantabrian. Lobate pecopterids found at 893 m make their first appearance at the Westphalian D and persist through the Stephanian, indicating that the barren redbed sequence above, nearly

900 m in thickness, is no older than Westphalian D. The presence or absence of Permian age strata within this interval, however, remains unknown.

Correlation of the subsurface record across Prince Edward Island holds regional significance for Permo-Carboniferous stratigraphy in the Gulf of St. Lawrence and has been undertaken by P. S. Giles of the Geological Survey of Canada Atlantic (Giles and Utting, 1999).

Paleontology of the Joggins Section

New insight into the paleontology of the Joggins Formation was advanced by the continuing field work and discoveries of Brian Hebert, student at Saint Mary's University, and through the collaboration of Andrew Milner, vertebrate palaeontologist at Birkbeck College, University of London, with whom collaboration was made possible by the author's receipt of a Palaeontology Research Grant from the Nova Scotia Museum.

The rare find by Brian Hebert of an intact lycopsid stump cast containing tetrapod bone material presented the opportunity to assess for the first time in a century the taphonomy of the Joggins tree stump fauna. The occurrence of this fauna is central to the community's application to the United Nations Educational, Cultural and Scientific Organization (UNECSO) for recognition of the Joggins section as a World Heritage Site (see next paper, this volume). A multidisciplinary research group, whose activities were jointly funded by DNR, the Fundy Geological Museum, and the Palaeontology Research Grant of the Nova Scotia Museum, included the author, Hebert, preparator Tim Fedak (Fundy Geological Museum), vertebrate paleontologist Milner (Birkbeck College, University of London) and paleobotanist Andrew Scott (Royal Holloway, University of London). Work on the specimen will continue at Fundy Geological Museum in 2000. It is hoped that this work will provide insight into the mechanism by which the Joggins tetrapods became entombed in the once hollow trees.

Important faunal discoveries from the lower Joggins Formation were found and prepared by B. Hebert at the Fundy Geological Museum. They include the now largest collection in the world of an enigmatic, rare, large unionoid bivalve, *Archanodon (Asthenodonta) westoni*. The discovery of a pelvic girdle, which may have affinities with the stem tetrapod group, the Baphetidae ('Loxommatidae'), represents the largest tetrapod yet discovered from the Joggins section. These discoveries, which will be described more fully elsewhere, provide important new insight into the paleo-ecology and sedimentary environmnent of the lower Joggins Formation redbeds.

Minerotrophic Coals of the Joggins Formation

The petrography, geochemistry and palynology of several coal beds from the Joggins Formation were investigated by Dr. J. C. Hower, Centre for Applied Energy Research, University of Kentucky, in collaboration with the author. The Joggins coals have been shown to be pervasively enriched in chalcophile elements, particularly zinc, arsenic and lead (Hower *et al.*, 2000). Zinc, in concentrations ranging up to 1.52 % (ash basis), commonly occurs as sphalerite infilling cell lumens in fusinite (charcoal). Arsenic and lead each may exceed 0.6 % (ash basis) in these high-pyrite coals, which are exceptional values for Euramerican coals.

Hydrocarbon Source Rocks

A project continuing since 1998 in collaboration with Dr. Prasanta (Muki) Mukhopadhyay, Global Geoenergy Research Ltd., entails sampling of possible hydrocarbon source rocks with specific attention to 'unconventional' sources in the coal measures of the Cumberland Group. The reader is referred to preliminary results in the field guide of the annual meeting of The Society for Organic Petrology (Calder *et al.*, 1998), which was co-hosted in Nova Scotia during 1998.

In 1998 and 1999, the mid-Devonian McAdam Lake Formation on Cape Breton Island was sampled as part of a broad sampling of the Maritimes Basin fill sequence. The occurrence of newly exposed organic-rich beds was brought to the attention of the author by Dr. Chris White (DNR), who recently co-described their geological setting (White and Barr, 1998). A 40 cm thick organic-rich bed approaching a coaly shale was sampled and submitted for organic petrography, vitrinite reflectance, palynology, Rock Eval pyrolysis and gas chromatography-mass spectroscopy. The extent and hydrocarbon potential of these rarely exposed sub-Horton rocks, which constitute the initial organic deposits of the Maritimes Basin, are as yet poorly understood. The McAdam Lake occurrence is of particular interest for hydrocarbon exploration because the organic-rich rocks record a surprisingly low maturation history ($R_o \sim 1.0$), given their age and stratigraphic position at the base of the Maritimes Basin succession.

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On the Nova Scotia Fossil Trail: A Progress Report on Community Economic Development of Fossil Sites in Nova Scotia

J. H. Calder

Background

Nova Scotia is endowed with twin gifts: a rich geological history and a dramatic showcase in which to display it. Perhaps nowhere else in the world is the story of the evolution of early life on land, including primeval forests and the earliest reptiles through to dinosaurs, so well and completely recorded as in the rocks now splendidly exposed in Nova Scotia's coastal cliffs. Singly, not all sites may rate World Heritage status, as Joggins may one day achieve. However, taken as a whole, their story is found nowhere else as completely as in Nova Scotia.

In 1996, the Nova Scotia Department of Natural Resources (DNR) gave formal recognition to the importance of community based economic development of certain major fossil sites, while honouring provincial legislation to protect our fossil heritage in concert with the Nova Scotia Museum (Calder, 1997). With initiatives now proceeding by a variety of community development agencies, it will be important to develop a province-wide strategy that embraces all sites and builds on the collective strength of Nova Scotia's fossil record, rather than allowing sites to compete for limited resources. Establishing a Nova Scotia Fossil Trail, drawing on the resources of several provincial departments, may be one way to enhance community economic development opportunities.

Status of Sites

Joggins (NTS 21H/09)

In 1998 the Joggins-River Hebert Development Association hosted a series of community meetings to gauge public support and identify any concerns with respect to initiating the process of seeking World Heritage Status from the United Nation's Educational, Scientific and Cultural Organization (UNESCO). Inscription on the World Heritage sites list would have a major positive impact, not only locally but for the province and greater Bay of Fundy region. An estimated 20,000 tourists currently visit the fossil cliffs each year; however, this number has the potential to swell several fold with World Heritage Site designation.

UNESCO has established comprehensive criteria that must be met before a site can be considered, which will require support at the community level, already demonstrated, but further at the provincial and federal levels of government to ensure that infrastructure will be in place and that site interpretation and protection will be ensured for future generations. From a scientific perspective, UNESCO (1972a) requires that a World Heritage Site be "*...of outstanding universal value*". Nominated geological sites should "*be outstanding examples representing major stages of the earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features...*" (UNESCO, 1972b). Further information on the World Heritage Convention and the process for "inscription" of sites can be found at the UNESCO website at www.unesco.org/whc/.

The major responsibility of the Department of Natural Resources in assisting Joggins and Nova Scotia to realize this important goal is to provide the scientific documentation that supports these criteria. To that end, research and documentation of the fossil record and its paleo-ecology, including new discoveries made in 1999, is being conducted in conjunction with Brian Hebert, Saint Mary's University, and preparator Tim Fedak, Fundy Geological Museum (see previous paper, this volume). Assistance to the locally run Joggins Fossil Centre is continuing through assistance in specimen identification, labelling and interpretation.

In 1999 an important step in this process occurred with the formation of a steering committee chaired by Joggins resident Mark Boon, under the authority of the Cumberland Regional Economic Development Agency (CREDA), and with representation from the Nova Scotia Department of Natural Resources and the Nova Scotia Museum. A prerequisite for World Heritage designation by UNESCO is institution of a management plan to demonstrate current and future protection of the site. Coincidentally, the Nova Scotia Museum, under terms of the *Special Places Protection Act*, is required to develop just such a management plan. Curator of Special Places Robert Ogilvie, in concert with the World Heritage Steering Committee, has consulted the Joggins community and incorporated their views in the museum's management plan.

Brule (NTS 11E/14)

At Brule (Fig. 1), scientific documentation of this recently discovered site reached a milestone with the submission at year's end of a comprehensive manuscript to the journal *Palaios* (Calder *et al.*, submitted). Under the direction of the Colchester Regional Development Agency (CoRDA) and the local North Shore Development Association, a community based Steering Committee has been instituted as a first step to incorporation as a charitable society. A provisional site for an interpretive centre in Tatamagouche is being evaluated, where selected material from the collection can be housed and displayed until funds are raised for more comprehensive infrastructure at the site.

Site mapping, excavation, specimen identification and interpretation, in co-operation with Howard van Allen of Dartmouth, continues in a challenging attempt to conserve the fossil record at Brule in the face of unrelenting tidal erosion. Late in 1999, the author received notice of the award of a scientific research grant from the Committee for Research and Exploration at the National Geographic Society, which will assist in funding work at the site and on the collection in the year 2000.

Sydney Mines (NTS 11K/01)

A feasibility study advising development of a fossil interpretive centre at Sydney Mines was commissioned by New Deal Development and conducted by Environmental Design and Management Ltd. of Halifax in 1998. An advisory board to New Deal was subsequently formed to consider and oversee implementation of the report's recommendations, with its first meeting held in 1999. Design for an interpretive centre was commissioned by New Deal from a consortium comprising Ojolick & Associates (Architects/Planners), and Communication Design Group. Scientific advice was provided to the board by the author and by Dr. Erwin Zodrow, University College of Cape Breton, on the structure and ecology of the Coal Age forests as represented at Sydney Mines. By year's end, the Fossil Advisory Board restructured to form an incorporated, not-for-profit organization, the Sydney Coalfield Fossil Society. The society has adopted as their objective "the development and interpretation of world class fossil sites in the Sydney Coalfield for the long term economic, educational, scientific and historical benefits of surrounding communities; and in particular, recognition and interpretation of the historical significance of fossil sites in Sydney Mines." The society is currently seeking to broaden its membership within the community, and New Deal has maintained its presence within the new entity.

In May 1999, at the request of the Fossil Advisory Board and New Deal, the writer undertook a speaking tour to schools in the Sydney Mines area to stimulate a sense of stewardship within the community. Presentations were delivered to four schools (Thompson Junior High, North Sydney; Dr. T. L. Sullivan, Florence; Sydney Mines Junior High; St. Joseph Elementary, Sydney Mines), reaching nearly 600 students.

A public fossil display and information centre, titled *Richard Brown & Family: Rocks, Fossils and Plants* was set up at the New Deal Development offices in Sydney Mines for the summer months, staffed by two students and supported by the Department of Natural Resources. The loan of fossil specimens and interpretative assistance were provided by Dr. Erwin Zodrow and the author.

Accessibility of the fossil cliffs adjacent to Shore Road in Sydney Mines, from which the concept of an interpretive centre first derived, remains a concern. The narrow, intertidal exposure on which to walk at the base of the overhanging cliffs remains a safety issue which has been recognized, but as yet unresolved. The area abounds with coastal exposures, however, providing alternate sites of geological and historical interest. These include standing fossil trees at the same stratigraphic horizon west of Cranberry Head and the serendipitous exposure nearby of a peat bog, the precursor to coal, where it endures erosion on the sea cliffs. These interpretive possibilities are currently being evaluated for the Sydney Coalfield Fossil Society by geologists Don MacNeil (DNR Coxheath) and Lynn Baechler with input from Erwin Zodrow and the author. A scientific paper describing the original section of Richard Brown and its fossil flora is in preparation, a collaboration between the author and A. C. Scott, of the Royal Holloway, University of London.

Challenges and Solutions

Community development agencies will encounter challenges as they move toward realizing opportunities presented by the fossil heritage in their areas. Some of these challenges include the following.

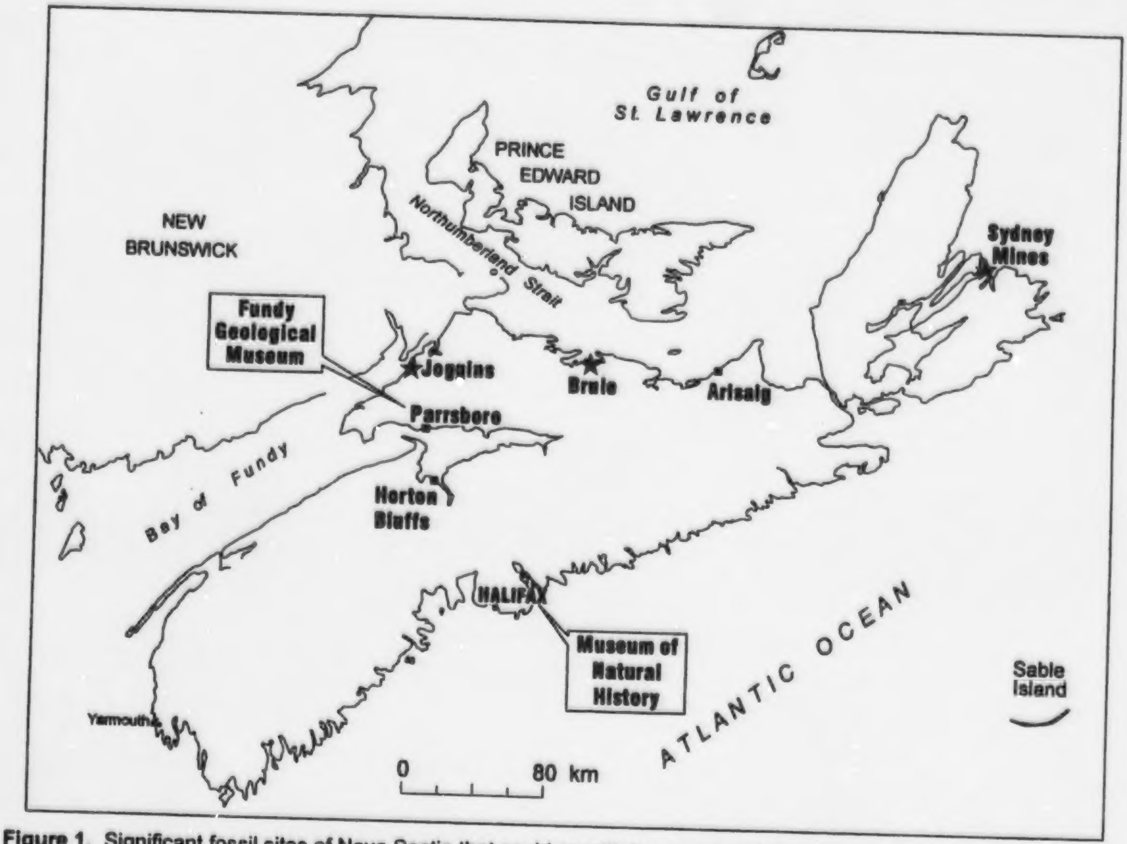

Figure 1. Significant fossil sites of Nova Scotia that could constitute a provincial 'Fossil Trail'. The scientific importance of these sites may render some inappropriate for ecotourism, depending on the nature of the fossils, their occurrence and abundance. Sites highlighted with a star are those with a component of public access and community development in place or planned.

Protection and sustainability of the fossil resource. This is the requisite starting point for any community based activity, and sites are protected under authority of the *Special Places Protection Act.*

Co-operation versus competition between communities concerned. It will be important to avoid duplication in the treatment of the subject matter covered at each site. The scientific overview provided by the Department of Natural Resources can help in this regard. Competition between communities for funding is yet another area of potential conflict that will require close linkages between community development groups and funding agencies.

Economic viability. Self sufficiency will require new funding strategies in the absence of government subsidy. Possibilities include corporate and private sponsorship, phased development, and revenue-generating programs.

Imaginative thinking. In the face of diminishing public funding and global competition for the increasingly astute tourist, it will be a challenge to develop innovative programs at each site and solutions to long-term financial viability. It will not be good enough simply to build an unimaginative facility and assume that people will come 'just because it is there'.

The province can help community development agencies in meeting some of these challenges by: (1) providing expertise in paleontology, interpretation, economics and tourism; (2) identifying resources that can be cost-shared between community development agencies; (3) fostering community stewardship of fossil sites; and (4) developing and promoting a provincial (or broader) concept. The concept of a Nova Scotia 'Fossil Trail', linking and promoting the various sites, is an example of a provincial concept that could deliver considerable assistance to communities. Community based projects of various scales, from simple guided walks without infrastructure to larger sites with interpretive centres, could participate, with the existing Nova Scotia Museum facilities serving as anchors. A 'Fossil Trail' may hold the key to strengthening the region's appeal and natural history resources rather than having individual sites compete with one another for the same resources of funds and visitors. Discussions between the departments of Economic Development, Natural Resources, and Tourism and Culture have begun to plumb the possibilities of such a concept.

Perhaps the most valuable assistance that the province can provide is open-minded support for imaginative approaches to funding and development by the rural communities of Nova Scotia.

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Geological Mapping and Mineral Inventory Studies in the Marble Mountain - Kennedys Big Brook Area (NTS 11F/14), Cape Breton Island, Nova Scotia

G. J. DeMont, M. A. MacDonald and P. W. Finck

Introduction

During the summer and fall of 1999, the Department of Natural Resources conducted geological mapping and mineral inventory surveys in the Marble Mountain-Kennedys Big Brook (North Mountain) area of Cape Breton Island, Nova Scotia (Fig. 1). Resource evaluations of industrial mineral prospects were the main focus of the mineral inventory component of this project, but a significant metallic mineral exploration target was also identified and evaluated.

The industrial mineral potential of the North Mountain area has been recognized for many years. The Marble Mountain quarry, which operated on a full time basis from 1886 to the early 1920s, supplied large quantities of high quality limestone to the Sydney Steel Mill and smaller quantities of building stone, construction aggregate, and plaster and agricultural lime for use in local markets. The quarry continues to be used sporadically as a source of white marble for use in construction and as decorative landscape aggregate.

Over the last two years, there has been a significant increase in the level of private sector interest in provincial limestone resources. Local and international investors require limestone for use as agricultural lime, feedstock for fluidized-bed power plants, and for producing cement. In addition, as a result of continuing development of the Sable Offshore Energy Project, there has been speculation about the construction of a

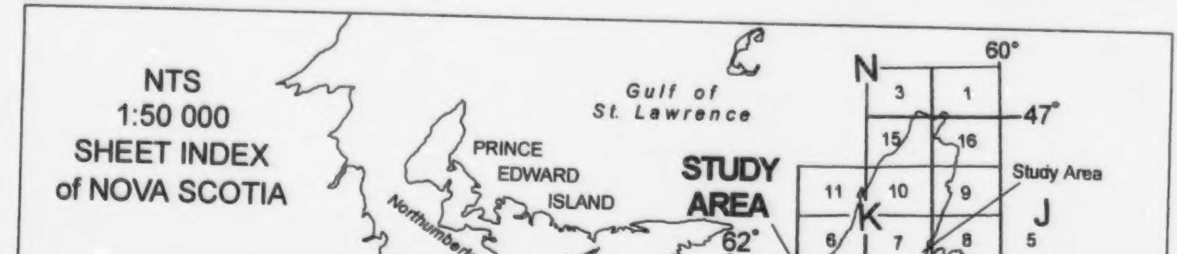

Figure 1. NTS index map of Nova Scotia showing location of the study area (NTS 11F/14).

petrochemical plant on Cape Breton Island. Should this plant be built in Nova Scotia, it could create demand for a local supply of mineral fillers, particularly, high-brightness, calcium carbonate fillers.

Anticipating this demand, the Department of Natural Resources conducted a literature review to determine which areas of Cape Breton Island might contain significant high-brightness calcium carbonate resources. Several areas on Cape Breton Island, such as Glencoe, North Mountain (Marble Mountain), Glendale and Cape Dauphin, are known to host white carbonate units which could contain economic quantities of high-brightness fillers.

Shipping cost is one of the significant factors used to determine the economic viability of any industrial mineral deposit. The decision to focus our studies on the North Mountain carbonate units was influenced by their proximity to the Bras d'or Lakes and to the Port Hawkesbury port facilities, rail sidings and roads.

Exploration surveys conducted in the North Mountain area in the 1980s outlined a red marble prospect along the north side of Kennedys Big Brook. This prospect is a potential source of high-value dimension stone so it was also flagged as an industrial mineral resource requiring further study.

Because of the varied resource potential in the North Mountain area, NSDNR initiated the project described in this paper during the 1999 field season. It was designed to confirm the findings of previous workers and to collect new data which might advance the department's ability to attract private sector development of these resources.

The project includes regional and site-specific, detailed geological mapping, geochemical and geotechnical analysis, examination and correlation of geological and geophysical data, and market investigations for various limestone-based products. Work will continue in the 2000-2001 fiscal year.

Surveys Conducted in 1999

Geological Mapping

Reconnaissance mapping surveys were conducted between River Denys and Marble Mountain, over areas underlain by Malagawatch Formation sedimentary rocks. The mapping was conducted primarily along the streams and roads, but several cross-country traverses were also made. A detailed grid, with 50 to 100 m line spacings was mapped over the Kennedys Big Brook red marble prospect (Fig. 2).

The geology of North Mountain, as illustrated on published geological maps, was for the most part found to be accurate. McFall's (1978) structural interpretation, which was based primarily on geological mapping conducted by Milligan (1970) and unpublished data collected by Dr. B. J. Keating, proved to be reasonable. However, during the study it became clear that more detailed mapping could produce significant refinements in local geology.

For example, numerous areas identified as white marble by Milligan (1970) were visited. The site locations and descriptions were determined to be accurate. During the current study, it was recognized that the geological maps available for this area were not detailed enough to resolve both the areal extent of these white carbonate units and their contact relationships with surrounding igneous and metamorphic rocks. In detailed examination, the spatial relationship of these white marble outcrops with other, dark-coloured carbonate units is highly complex. This relationship must be understood because it has a significant impact on the economic potential of the white marble units.

Outcrop data collected in the field were compiled in Auto-Cad® using the Geological Survey of Canada's Fieldlog® database program. Geological data from previous mapping by Milligan (1970), McFall (1978), Hill (1987) and Justino (1991) were still being compiled into our digital database at the time this report was written. A new 1:25 000 scale geological map incorporating all these data will be released with a final project report in the spring of 2000.

Aeromagnetic and airborne VLF-electromagnetic data collected by the Geological Survey of Canada (GSC) were reprocessed and proved to be very useful in defining lithologic contacts. GSC airborne radiometric data were also obtained and reviewed for this purpose.

Mineral Inventory Studies

Site visits were made to the reported metallic and industrial mineral occurrences found in the study area. Rock samples were collected at all the sites and an attempt was made to fit these occurrences into the regional geological setting. Results of the sample analyses and field studies will be compiled and added to the Mineral Occurrences Database. These results will also be released in the final project report and accompanying geological map.

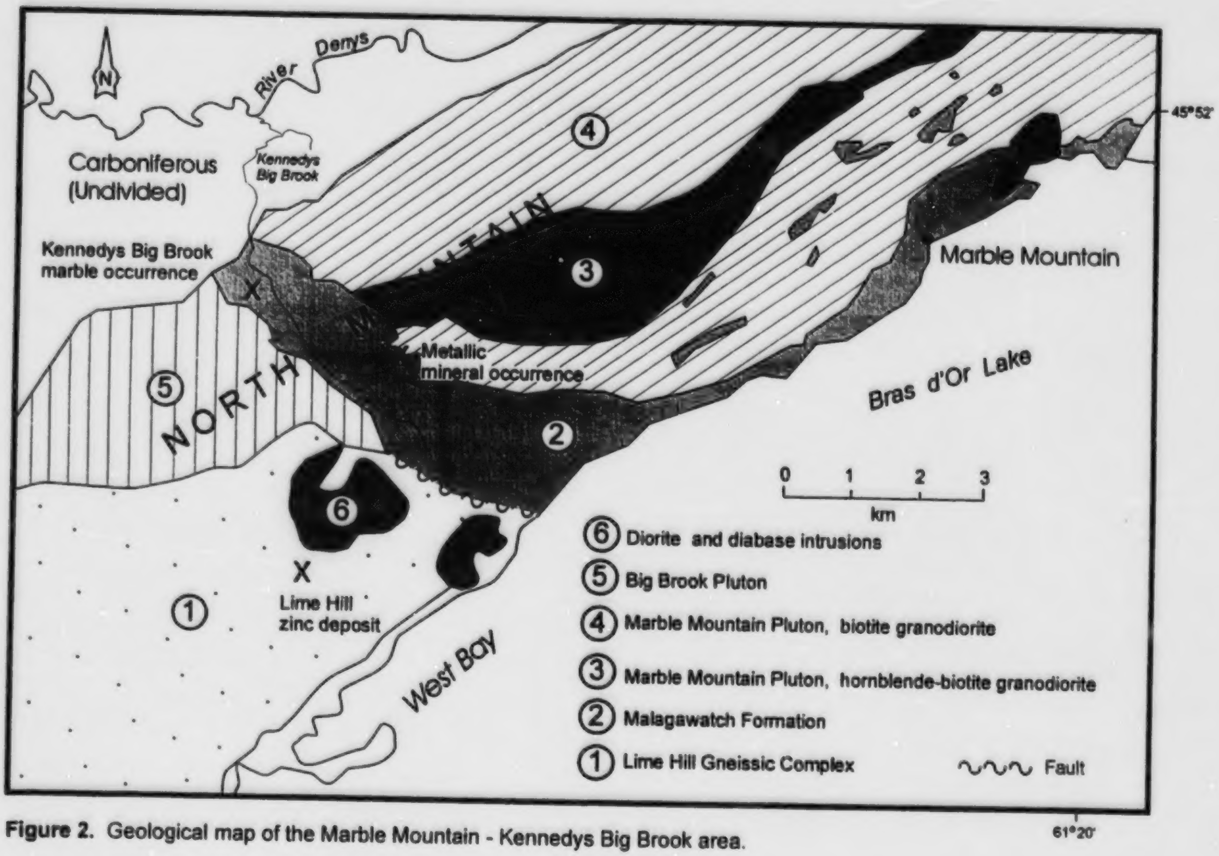
N
River Denys
Carboniferous (Undivided)
Kennedys Big Brook
Kennedys Big Brook marble occurrence
NORTH
Metallic mineral occurrence
Marble Mountain
Bras d'Or Lake
West Bay
Lime Hill zinc deposit
X
X
45°52'
61°20'
0 1 2 3
km
⑥ Diorite and diabase intrusions
⑤ Big Brook Pluton
④ Marble Mountain Pluton, biotite granodiorite
③ Marble Mountain Pluton, hornblende-biotite granodiorite
② Malagawatch Formation
① Lime Hill Gneissic Complex
Fault
①
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Figure 2. Geological map of the Marble Mountain - Kennedys Big Brook area.

Geochemical Surveys

Till and stream sediment geochemical surveys were conducted over a small portion of the study area in an attempt to outline the metallic mineral potential, and in particular, to test a mineralized fault structure described in following sections of this report. Details of the survey methods and results are discussed in Goodwin (this volume).

Geological Setting

The study area (Fig. 1) is located along North Mountain, a prominent, northeast-trending upland region which parallels Bras d'Or Lake between West Bay Road and Malagawatch (Fig. 2). This upland region is underlain by a mixture of Precambrian carbonate and clastic metasedimentary rocks and Late Cambrian to Ordovician intrusions of varied composition.

North Mountain is roughly bisected by the Kennedys Big Brook Valley. North and east of the valley, the bulk of the upland block is underlain by the Marble Mountain Pluton. The valley itself is underlain by clastic and carbonate sedimentary rocks of the Malagawatch Formation. South and west of the valley the upland block is underlain by clastic and carbonate metasedimentary rocks of the Lime Hill Gneissic Complex and the Big Brook and West Bay plutons.

Carbonate and Clastic Metasedimentary Rocks

The carbonate and clastic metasedimentary rocks, which are the focus of this study, were included as part of the George River Group by Kelley (1968) and Milligan (1970). However, more recently Justino (1991) subdivided these rocks into the Lime Hill Gneissic Complex and the Malagawatch Formation (Fig. 2).

The Lime Hill Gneissic Complex consists primarily of migmatitic paragneiss and less abundant orthogneiss, marble, amphibolite and calc-silicate rocks. The gneissic rocks underwent several phases of folding and were regionally metamorphosed to upper amphibolite facies under low-pressure conditions (Justino, 1991). These rocks have been correlated with other low-pressure gneiss units exposed on Cape Breton Island and are estimated to be of Late Proterozoic age (Justino, 1991). The Lime Hill zinc deposit is hosted by carbonate units of the Lime Hill Gneissic Complex.

The Malagawatch Formation is exposed in a narrow band which parallels the shore of West Bay (part of Bras D'Or Lake) between Lime Hill and Malagawatch, and in a broad belt located near the centre of North Mountain, along the Kennedys Big Brook Valley. This formation consists of metapelite or argillite, calcitic and dolomitic marble, quartzite, and minor mafic to intermediate metavolcanics. These rocks were regionally metamorphosed to chlorite or biotite facies, and locally exhibit contact metamorphism near pluton margins. This formation has been correlated with similar units found elsewhere on Cape Breton Island which have been dated as Late Proterozoic (Justino, 1991). Justino and Sangster (1987) suggest that the Lime Hill Gneissic Complex represents either a block of Malgawatch Formation which was uplifted from a deeper structural level, or a faulted-in section of pre-Malagawatch Formation basement of undetermined age.

East of the Kennedys Big Brook Valley, along the west side of West Bay, bedding in the Malagawatch Formation trends northeast. However, along the brook valley, bedding trends northwest. This change in bedding orientation presumably reflects post-depositional faulting, folding or a combination of the two.

Intrusions

Justino (1991) mapped three principal intrusions in the North Mountain area: (1) the Marble Mountain Pluton, (2) the Big Brook Pluton and (3) the West Bay Pluton. Two smaller intrusions were also mapped by Justino (1991): a small diorite body along Mill Brook and a small tonalite body along the southwest end of the Big Brook Pluton.

The Marble Mountain Pluton consists of medium- to coarse-grained granodiorite to tonalite. Justino (1991) subdivided the pluton into two units, hornblende-biotite granodiorite and biotite granodiorite. Both hornblende-bearing mafic xenoliths and metasedimentary xenoliths, mainly marble, occur in the pluton. The pluton displays a northeast-trending tectonic fabric defined by a poorly developed mineral alignment and preferred orientation of elongate mafic and metasedimentary xenoliths. The Big Brook Pluton consists of relatively homogenous, generally massive biotite tonalite to granodiorite (Justino, 1991). Hornblende-bearing mafic xenoliths are present but sparse. The West Bay Pluton, which consists of monzogranite, is located along the southwest end of North Mountain and does not outcrop in the study area.

Justino (1991) made the following conclusions regarding the Big Brook and Marble Mountain plutons: (1) both plutons are considered to be derived from the same source, but major and trace element trends indicate separate evolutionary histories; (2) both plutons are calc-alkalic and display mineralogical and geochemical features typical of I-type granitoid rocks; and (3) the major and trace element characteristics of both plutons indicate they were formed in a magmatic arc environment.

Both the Marble Mountain and Big Brook plutons intrude medasedimentary rocks of the Malagawatch Formation. Justino (1991) described localized contact metamorphism in some of the metapelite or argillite units. However, with the exception of a small area of garnet skarn reported along Mill Brook, contact metamorphism is not apparent in the carbonate outcrops where observed in the study area. Contacts between the intrusions and marble are sharp and steeply dipping.

Carboniferous Sedimentary Rocks

With the exception of its eastern side, which abuts Bras d'Or Lake, the flanks of North Mountain are unconformably overlain by a thick cover of Carboniferous sedimentary rocks. Along the north side of the upland, Horton Group conglomerate is exposed near the top of the hill, but for the most part Carboniferous rocks are found in lowland areas.

Structure

The Lime Hill Gneissic Complex and the Malagawatch Formation are separated by a northwest-trending fault which roughly bisects North Mountain (Milligan, 1970; Justino, 1991). Determination of the precise location, dimensions, and sense of motion of this fault structure is incomplete. Airborne magnetic maps covering this area illustrate that the rocks affected by this fault occur in a broad band that follows a northeast trend in the Marble Mountain area, and a northwest trend along the Kennedys Big Brook Valley. This inflection in magnetic signature coincides with a change in bedding and structural fabric orientations observed in sedimentary rocks of the Malagawatch Formation.

In the Malagawatch Formation, the fault is characterized on the ground by localized breccia zones, fault scarps, drag folds and boudinaged beds. Fault-related deformation in the Marble Mountain Pluton includes localized schistose fabrics, protomylonite, a weak overall mineral alignment and localized breccia zones. The linear structural features attributed to faulting also parallel the aeromagnetic and bedding trends described above.

Some breccia zones observed in the Malagawatch Formation were initially thought to represent fault-related deformation, but a more detailed examination suggested that they could represent areas where beds ruptured during folding, or where slippage occurred along bedding surfaces.

Two distinct sets of folds have been mapped in the Malagawatch Formation. The axis of one set trends northwest and appears to plunge steeply to the southeast. Superimposed on these folds is a set of east- to northeast-trending folds which appears to plunge to the southwest (McFall, 1978). Northeast-trending parasitic folds with nearly horizontal dip were also observed near Marble Mountain.

McFall (1978) and Milligan (1970) mapped the second fold set in an area located along the south side of the study area, but during the present study this same fold set was recognized along the north side of Kennedys Big Brook. These folds appear to have played a key role in development of the red marble prospect.

The folds were identified in the vicinity of the red marble prospect where grid mapping provided detailed outcrop and stratigraphic control. Although the folds were not observed in the field, they became apparent when the outcrop data for two dolomite marker beds were plotted. The position of these folds correlates with topographic depressions in linear, northwest-trending marble ridges. These ridges, which roughly parallel bedding orientations, appear to represent anticlines produced during the first folding event. However, further structural measurements are required to confirm this hypothesis.

Weathered surfaces on the dolomite marker beds were noted to have a characteristic pale brown colour and a rough, gritty, alligator skin texture. Dolomite beds were previously unmapped, because in many places within the study area these beds have been partially or fully replaced by secondary calcite. All the weathered outcrop surfaces should be examined in detail. On fresh outcrop surfaces, and in hand specimen, it is often difficult to differentiate between calcitic and dolomitic marbles.

Hydrothermal Alteration

Previously undocumented, widespread hydrothermal alteration was identified in the study area. Fault-related deformation features provided the primary pathway for movement of a metal-rich hydrothermal fluid. However, localized breccia zones and fractures associated with the two stages of folding described above also channeled hydrothermal fluid through the carbonate units. Zones of hematite and carbonate alteration observed throughout the study area are interpreted to result from this fluid.

Fracture- and vein-controlled hematite alteration is common in the Malagawatch Formation quartzite and carbonate rocks. Locally, where hematite alteration is more intense and pervasive, the carbonate units are pale pink to dark red.

White, fracture-controlled calcite veins are common in the both calcitic and dolomitic marble units. These veins commonly contain hematite which occurs as: (1) the red earthy variety, and (2) fine- to coarse-grained specularite crystals. Dolomite and siderite also occur in some of the calcite veins. However, the degree to which these two minerals are present in the veins is difficult to judge because both minerals are only apparent on weathered outcrop surfaces.

Siderite alteration occurs as pervasive replacement of certain primary carbonate beds, as veins found both in the carbonate and argillite or metapelite units, and as fracture coatings in brecciated quartzite and carbonate units. Siderite alteration appears to postdate the hematite alteration phase because, where they occur together, siderite alteration crosscuts or overprints the hematite-altered zones.

A gradual change from the typical dark, blue- or greenish-grey to a pale-grey or even white is apparent in some of the carbonate outcrops. This colour change appears to result from: (1) metamorphic recrystallization of the primary carbonate beds, or (2) replacement of the primary carbonate beds by secondary calcite introduced by a hydrothermal fluid. In some instances, this colour change is accompanied by a distinct increase in the grain size of calcite crystals. This phenomenon requires further study.

Sulphide mineralization, which is associated with silica alteration, is also localized along the fault structure described above. This alteration is described in more detail under the mineral occurrence section of this paper.

Geophysical Data Interpretation

Mr. M. S. King was contracted to reprocess the Geological Survey of Canada aeromagnetic and VLF-EM data for the study area. Both second derivative and total field magnetic maps were produced from the reprocessed aeromagnetic data. Four digital map images were produced from the VLF-EM data: (1) inline total field, (2) orthogonal total field, (3) inline fraser-filtered quadrature, and (4) orthogonal fraser-filtered quadrature. These data, which were not previously available in this format, proved to be useful for interpreting the position of both lithologic contacts and structural lineaments. Both data sets illustrate several interesting features.

Along the east side of North Mountain the break between the two phases of the Marble Mountain Pluton, as mapped by Justino (1991), coincides with a distinct change in the form and signature of the aeromagnetic data. The biotite granodiorite phase of the pluton coincides with an area defined by elongated, northeast-trending magnetic highs and associated, parallel magnetic lows.

There is a fair correlation between the location of magnetic lows and the mapped position of the Malagawatch Formation metasedimentary rocks. However, the correlation is not strong because some of the magnetic lows also correlate with the mapped position of biotite granodiorite outcrops. For the most part, the position of biotite granodiorite outcrops correlates well with the position of the linear magnetic highs, a magnetic signature which apparently reflects the magnetite or ilmenite content of the biotite granodiorite. The diorite intrusion found along Mill Brook also coincides with a magnetic high.

Along Kennedys Big Brook Valley, both the magnetic highs and lows parallel the orientations observed in the bedding and structural fabrics described above. Although the magnetic data appear to be a useful mapping tool in the North Mountain area, further geological mapping, ground magnetometer and magnetic-susceptibility surveys should be conducted to clarify the relationship between the aeromagnetic anomalies and underlying rock units.

The Geological Survey of Canada provided airborne radiometric data for this study, but it did not prove useful as a detailed mapping tool. It was found that the 1 km flight line spacing did not provide enough data resolution to allow us to distinguish map scale rock units.

Mineral Inventory Studies

Industrial Mineral Prospects

Zones of intense hematite alteration are characterized by a distinct pink to red colour change in the otherwise greenish-grey to black marble. Red marble, which is in demand for use as flooring tiles, is one of the highest priced building stones found in the marketplace. Although hematite alteration is found in the marbles throughout the study area, the red areas exhibiting intense, pervasive alteration, which could be considered as sites for commercial marble quarry operations, occur only in localized areas. However, these zones are large enough to suggest that they could contain red marble deposits of economic size.

Geological mapping and mineral inventory studies conducted this year were designed to identify sites for a commercial red marble quarry operation. These studies identified three potential sites located on top of the mountain along the north side of Kennedys Big Brook (Nova Scotia Department of Natural Resources, 2000). Structural deformation in the host marble at each of these sites allowed for a concentrated influx of hydrothermal fluid, resulting in pervasive reddening of the marble. The sites occur where stage two folds are superimposed on stage one folds, in proximity to the projected position of the mineralized fault described above. Fracturing and localized rupturing or brecciation of the carbonate beds associated with the second stage folds appear to have been a controlling factor in the location of the intense alteration found at these sites.

Black, white and cream marble units found in the study area have potential for use as a building stone, but the market value of this material is considerably lower than that of red marble. White marble found in this area could be a significant resource for use as high brightness fillers, but further mapping and sampling is required to clarify their areal extent and chemistry.

Whole-rock geochemical analyses were completed on several white, grey and black marble samples collected in the study area. These analyses will be useful for anyone interested in evaluating these units as a source of agricultural, cement- and filler-grade calcium carbonate.

Metallic Mineral Occurrences

Sulphides of As and Sb are exposed at two locations in the study area. A third mineralized site was defined by the 1999 till geochemical survey (Goodwin, this volume). Small amounts of disseminated pyrite (1-3%) and trace amounts of arsenopyrite were encountered in brecciated quartzite and argillite or greywacke units intersected in a diamond-drill hole drilled by Nova Scotia Department of Mines in 1961 (Milligan, 1970).

The most interesting occurrence (Nova Scotia Department of Natural Resources, 2000) is exposed in the bed of a northeast tributary of Kennedys Big Brook, where sub-massive pyrite, with lesser amounts arsenopyrite and stibnite, occurs as matrix filling in brecciated quartzite and marble. No Au or Ag mineral phase was identified in the hand specimens collected from this outcrop, but analyses of these specimens indicate they contain weakly anomalous concentrations of both elements. The sulphides are associated with silica, and to a lesser extent, carbonate alteration of the marble and quartzite. Granodiorite is exposed in outcrop a few metres away from the mineralized outcrop, but is not mineralized. However, shearing and carbonate alteration are both evident in this exposure.

Conclusions

Detailed mapping of dolomite beds proved to a be a useful tool in defining fold structures which had previously gone unrecognized. The folds are interpreted to have influenced the movement of mineralizing fluid and, therefore, the degree of reddening (hematite alteration) found in the marble units. Defining the areal extent of red marble units was one of the principal goals of the 1999 surveys, so mapping of these folds is critical to the success of the exploration survey.

Hydrothermal alteration in the study area made it difficult to map the dolomite beds because they were often partially or wholly replaced by secondary carbonate. To map these units, great care must be used when examining the weathered surfaces of the marble outcrops because it is only on these weathered surfaces where the dolomite component of the outcrop becomes apparent. Precambrian dolomite is characterized on weathered surfaces by a pale brown colour and a gritty, alligator skin texture. However, in areas of intense hydrothermal alteration, only minute traces of this texture remain visible on the outcrop surface.

The areal extent of sulphide mineralization was not determined in this study. To date, the data collected on these occurrences suggest that there is significant potential in the area for the occurrence of a structurally controlled, polymetallic gold deposit. Anomalous concentrations of Au, Ag, Sb, As and Hg associated with sulphide mineralization suggest that the exploration target may be an epithermal or mesothermal vein deposit. In any event, our study defines this area as a valid exploration target.

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Stimulating the Mineral Industry with Prospector Assistance

H. V. Donohoe, Jr.

Purpose

The Prospector Assistance Program (PAP) was designed to help prospectors learn prospecting skills, to provide a financial contribution toward working a mineral claim and to assist in marketing mineral properties. Although the idea of prospector assistance is not new, the current program, which began in 1997, is different than previous prospector programs.

Importance of Prospectors

The 'grass roots' of successful mining relies on a local community of prospectors involved in searching for new deposits and carrying out exploration on known mineral occurrences. Their work makes mineral occurrences and deposits attractive to investors and mining companies.

Over the past ten years the exploration component of the mineral industry has changed significantly in Canada and Nova Scotia. Most mining and exploration companies have dramatically reduced their exploration staffs and curtailed the resources they would need for exploration. The result is a significant reliance on prospectors to find mineral properties, prospect them, and undertake geological, geochemical and geophysical surveys as needed. At the same time more exploration capital is moving to Central America, South America and other parts of the world.

Prospectors have now assumed a stronger role in mineral exploration than they have in the past. They have always been part of the mineral industry at its 'grass roots', but now prospectors are expected to work a property to a higher level of development. The industry's greater reliance on prospectors to do additional work creates a need for training, continuing education, financial assistance and marketing support. The Prospector Assistance Program in Nova Scotia is designed to accomplish all of these.

History

Prospector assistance programs began in the early 1990s as part of the Canada-Nova Scotia Cooperation Agreement on Mineral Development (CNSCAMD). The Prospectors Assistance Program under the most recent CNSCAMD (1992-1995) was one of the most popular programs under this agreement and the results were gratifying. There are now over 640 registered prospectors with approximately 240 companies or individuals holding one or more mineral licences in the province. Approximately 150 prospectors received assistance grants for work on their properties between 1992 and 1995. During the same time over 200 people took the basic prospecting course and 12 took the first offering of the advanced prospecting course.

The CNSCAMD also provided limited financial assistance to attend trade shows for marketing mineral properties. Many prospectors attended the Prospectors and Developers Association of Canada meeting in Toronto and were able to interest companies in their properties.

Current Prospector Assistance Program

The current Prospector Assistance Program builds on the past experience of the CNSCAMD. The Nova Scotia Department of Natural Resources has brought together all parts of prospector assistance into one program instead of several. The program is funded by the Canada-Nova Scotia Cooperation Agreement on Economic Diversification, which is jointly administered by the Nova Scotia Department of Economic Development and Tourism and the Atlantic Canada Opportunities Agency (ACOA). The agreement has a value of $600 000 over fours years and will end in 2001. Over the four year life of the program, each of the three components is receiving solid support. Table 1 provides the budget for each component of the program.

The Prospector Assistance Program has been successful in obtaining the support of the prospecting community. Shortly after the program was made official in August 1997, the Mineral and Energy Resources Division hosted a workshop for stakeholders. Representatives of the prospecting community at large, the Prospectors Association of Nova Scotia, the Mining Society of Nova Scotia and the Chamber of Mineral Resources of Nova Scotia met with division staff to

Table 1. Budget for the Prospector Assistance Program.

Component	Year 1 1997-98	Year 2 1998-99	Year 3 1999-00	Year 4 2000-01	Component Total
1. Training	$15 000	$ 25 000	$ 20 000	$ 20 000	$ 80 000
2. Assistance	$20 000	$100 000	$140 000	$140 000	$400 000
3. Marketing	$30 000	$ 30 000	$ 30 000	$ 30 000	$120 000
Yearly Totals	$65 000	$155 000	$190 000	$190 000	
				Total Amount of PAP	**$600 000**

review the guidelines and operating procedures of the PAP. The department launched the program at the annual Minerals and Energy Branch Review of Activities in November 1997.

The PAP is co-ordinated by the author, who is assisted by a committee comprising Dr. Michael Cherry, Director of the Mineral and Energy Resources Division, and geologists Michael MacDonald, Ron Mills and Paul McCulloch.

Program Components

The program has three components: (1) prospector training, (2) prospector assistance, and (3) marketing assistance. Although each component is independent of the others, all three are integrated in a uniform approach to encourage the development of the province's mineral potential.

Prospector Training provides support for training entry level prospectors at different locations throughout Nova Scotia. An advanced course is offered as demand warrants and gives additional experience and practice to those prospectors who have graduated from the basic course. The demand for training has been high. We have delivered basic prospecting courses in various parts of the province. Since the PAP began in 1997, 227 people have taken basic and advanced prospecting courses. Graduates of the courses rate the course content and the instructors very favourably. Table 2 lists the locations of courses and the number of graduates in the past several years.

Prospector Assistance provides a base level of financial support for individual prospectors to search for new mineral deposits and to attract exploration activity by larger companies. Both the PAP and the prospector contribute toward the funding of a project. If a prospector has an application approved for the maximum amount of $5 000, then he or she is required to contribute a minimum of $1 500 to the project. Prospectors may choose to pay for some of their out-of-pocket expenses and in-kind work with their share. Although they only need to contribute a maximum of 30% toward their project, prospectors often contribute considerably more. In year 2 (fiscal 1998-99) prospectors contributed an additional 57%, or 27% above the minimum required amount. In year 3 (fiscal 1999-2000) prospectors may contribute as much as 70% additional funds (or 40% above the minimum). The modest funding levels for the prospector assistance component are returned many times over by contributions, both monetary and in-kind work, from the prospectors. The number of projects and their targets are shown in Table 3. In year 3 the 28 projects are evenly distributed across the province (Table 4).

Marketing Assistance is designed to assist in promoting and marketing a prospector's mineral claims. Most of the marketing work is conducted at national and international trade shows. These provide unparalleled venues to present Nova Scotia's mineral potential and investment opportunities to mining companies and industry representatives. Marketing assistance for prospectors provides financial assistance to travel to trade shows, to display information about and samples from properties, and to make contacts with industry people. Table 5 lists the various trade shows and the number of prospectors attending in the first three years of the program.

Measures of Success

Prospectors have been enthusiastic in supporting the PAP. Each of the prospector training courses has been filled and many of the graduates have staked claims. Interest in the prospector assistance contributions was so great in 1998 that we could only fund the first 22 applicants of a total of 36. As many as 80 prospectors will have benefited from prospector assistance contributions to work their mineral claims. From

Table 2. Location of prospecting courses.

Year	Total Number of Students	Locations of Basic Course	Locations of Advanced Course
1997, Fall	45	Port Hawkesbury, Halifax	Not offered
1998, Spring	63	Sydney, Halifax, Bridgewater	Halifax
1998, Fall	44	Stellarton, Halifax	Not offered
1999, Spring	29	Stellarton, Windsor	Stellarton
1999, Fall	46	Halifax, Sydney, Stellarton	Not offered
2000, Spring	30-50	Halifax, Wolfville, Parrsboro, Sydney	Middle Musquodoboit

Table 3. Summary of prospector assistance component applications.

Calendar Year	PAP Year; Fiscal Year	Number of Prospectors	Target Minerals
1997	Year 1, 1997-98	0	Prospector assistance component funding deferred to 1998.
1998	Year 2, 1998-99	22	vein and disseminated gold; paleoplacer gold; kaolin; base metals
1999	Year 3, 1999-00	28	vein and disseminated gold; paleoplacer gold; barite/fluorite; base metals; kaolin
2000	Year 4, 2000-01	26 to 30	vein and disseminated gold; zinc; paleoplacer gold; base metals; kaolin

Table 5 it is clear that prospectors have appreciated the support for marketing their properties. In the first three years of operation, 46 prospectors have received financial assistance to travel to trade shows and market their mineral properties or products.

Another measure of success is how the mineral industry views the properties offered at various trade shows. Companies in Australia, South Africa, United States as well as Canada have expressed interest in the properties marketed by Nova Scotia prospectors either through the book *Properties for Option in Nova Scotia* or at trade shows. Some of the interest has resulted in option agreements.

What does the province get for the modest investment in the PAP? Prospectors locate and define more mineral occurrences and deposits in the province. Their work assists the Nova Scotia Department of Natural Resources to promote the province's mineral potential and geological environments. If just one prospector project goes into production, the amount of capital expenditures for infrastructure, wages, taxes and other benefits will dwarf the modest investment of $600 000 by a factor of 100 to 1000.

Importance of the Program for Nova Scotia

Prospecting is the grass roots of the mineral industry. Without a trained and motivated community of prospectors, many of the mineral deposit discoveries that we need for future production will not be made. In this sense prospectors are the future of the industry.

In Nova Scotia the Prospector Assistance Program is successfully providing training, financial assistance and marketing assistance. We believe, along with our partners, that successful prospecting is essential to the mineral industry. When prospectors succeed in bringing companies to the province for further exploration and development work they are contributing toward economic benefits. If some of these mineral properties are eventually brought into production as mines, then Nova Scotians benefit from the creation of wealth and employment.

Table 4. Prospector assistance component projects by region in year 3 (1999-2000).

	Prospector's Name	PAP Number	Target Commodity	Property Name
			Western Region	
1	Ian Booth	C99-004	Zeolites (Mordenite)	North Mountain
2	Lyndon Jensen	C99-006	Gold	Brookfield Gold District
3	Gary Monett	C99-009	Gold	Blockhouse Gold District
4	Alan Hooper	C99-011	Gold	Whiteburn Gold District
5	John Whiteman	C99-013	Kaolin	Bridgetown area
6	Henry Bent	C99-015	Kaolin and Zeolites	North Mountain in the Bridgetown area
7	John Lindsey Allen	C99-018	Gold	South Shore Gold Districts and adjacent areas
8	Trevor Hayward	C99-024	Gold	Molega Gold District
9	Hubert Burrill	C99-025	Base metals, Gold	Nickersons Point area, Brenton area, Yarmouth County
			Central Region	
1	John MacIsaac	C99-001	Base metals and Barite	Cheverie area
2	David Hutchings	C99-002	Base metals and Barite	Cheverie area
3	Joey Collier	C99-005	Gold	South Branch Stewiacke River
4	Curren Jensen	C99-008	Gold	Central Rawdon Gold District
5	Avard Hudgins	C99-014	Base metals (Zinc)	Far Brook, Gays River area
6	Dale Watters	C99-019	Building Stone	Amherst Quarry
7	John McCara	C99-020	Building Stone	Scotsburn Stone quarry
8	Roland Anthony	C99-022	Gold (placer)	Little Meander River
9	Greg Morris	C99-023	Base Metals	Mt. Thom area
			Eastern Region	
1	Tony Barrett	C99-006	Kaolin	Brierly Brook
2	Henry Schenkels	C99-010	Gold	North Ogden (Guysborough County)
3	Joe Richman	C99-012	Kaolin	Brierly Brook
4	Ted MacNaughton	C99-021	Gold	Wine Harbour Gold District
5	Gaye Johnson	C99-026	Base Metals, Gold	MacLeod Brook, SE Cape Breton Highlands
6	Diane Smeltzer	C99-027	Andalusite	Lundy, Guysborough County
7	John Burton	C99-028	Gold	Gold Mine Brook near Barachois River, SE Cape Breton Highlands
8	Clayton Fraser	C99-029	Gold	Barachois River, SE Cape Breton Highlands
9	Eric Fraser	C99-30	Gold	Barachois River, SE Cape Breton Highlands
10	Richard Tudor	C98-013	Gold	SE Cape Breton Highlands

Table 5. Trade shows attended by prospectors.

Date; PAP Year; Fiscal Year	Location	Trade Show; Types of Properties	Number of Prospectors
January 1998 Year 1 1997-98	Vancouver	British Columbia and Yukon Chamber of Mines's Cordilleran Roundup; disseminated and vein gold	3
March 1998 Year 1 1997-98	Toronto	Prospectors and Developers Association of Canada; paleoplacer gold, vein gold, base metals, rare earths	14
January 1999 Year 2 1998-99	Vancouver	British Columbia and Yukon Chamber of Mines's Cordilleran Roundup; paleoplacer gold, barite/ fluorite, base metals	4
January 1999 Year 2 1998-99	Toronto	Landscape Ontario trade show; various styles and sizes of shaped granite cobbles and granite tiles	1
March 1999 Year 2 1998-99	Toronto	Prospectors and Developers Association of Canada; vein and disseminated gold, base metals, barite	12
June 1999 Year 3 1999-00	Halifax	Municipal Expo; various styles and sizes of shaped granite cobbles and granite tiles	1
January 2000 Year 3 1999-00	Vancouver	British Columbia and Yukon Chamber of Mines's Cordilleran Roundup;	4
March 2000 Year 3 1999-00	Toronto	Prospectors and Developers Association of Canada; vein gold in former gold districts; paleoplacer gold; zinc skarn deposits; sedimentary zinc deposits; base metals.	12

Digital Information Services

B. E. Fisher, J. C. Poole and J. S. Saunders

The Digital Information Services group is responsible for developing and maintaining the Minerals and Energy Branch (MEB) Geographic Information System and associated databases, the NovaScan bibliographic geoscience database, for supplying digital data and services to clients and staff, and for developing the MEB internet web site. Permanent Digital Information Services staff consist of geologists Brian Fisher and Jeff Poole, and word processor operator Susan Saunders. Krista Fraser, a GIS specialist (left in May 1999), Gayle Chapman, Michelle Williamson and Megan Surrette, all geology students (left in August), and Angela Murphy, a planning and land information technology graduate, have worked with the group on a casual basis over the past year.

Digital Geoscience Data Products

A collection of digital geology maps, databases and images (in DXF, ARC export format, or as TIFF images in a UTM projection using the NAD27 datum) on Nova Scotia has been developed and is now on sale through the library and available for free download from the MEB web site at http://www.gov.ns.ca/natr/meb/pub3.htm. The complete list of digital data products available is in Appendix 3. This list can be obtained from the Nova Scotia Department of Natural Resources (DNR) Library in Halifax or viewed on the MEB web site at http://www.gov.ns.ca/natr/meb/pubshome.htm. A licence agreement is issued with all digital data sets. This agreement allows unrestricted use of the data with the understanding that DNR remains the owner of the data and is not transferring copyright to the user. Since March 1999, when the downloadable data were made available on the web site, there have been a total of 3611 downloads.

Public Access GIS

A public access GIS has been developed for use by clients in the Halifax Library. This is a user-friendly query and display system which uses a customized version of ArcView® to access a variety of geographically referenced digital geoscience data. It can display and query data sets, overlay various themes of geoscience, topographic and land-use information, and output the resulting maps as coloured plots. Version 2 of the public access GIS has been released. It has been upgraded to work in ArcView® 3.1, and includes new labelling and drawing capabilities, the ability to create shapefiles, to add a georeferenced grid to the layout, and many other new features. Version 3 is currently being worked on and will contain many new themes and an improved menu system. This version should be available in early 2000.

GIS Development

Digital Information Services staff have been working cooperatively with other MEB staff on several projects. In conjunction with the land-use staff, they are continuing to convert the Mineral Resources Land-Use (MRLU) Maps for Nova Scotia into digital form. The new 1:500 000 *Geology Map of Nova Scotia* is completed and was released as published Map ME 2000-1 in January 2000. Work on integrating the Registry of Mineral and Petroleum Titles database into the GIS and automating the production of the *Mineral Claims Disposition Map* has been completed. This database will be available in version 3 of the public access GIS. Work is continuing on converting the NovaScan database into ARC/INFO® format. When completed, the database will be made available in the public access GIS and on the internet early in 2000. Work by Gayle Chapman and Michelle Williamson on a new composite geology map of Nova Scotia continued. Work has been completed on the initial digitizing and verification of 45 geology maps, including the geological line work and over 60 000 data points and their attributes, using AutoCAD® and Fieldlog®. Many of these maps have been converted to ARC/INFO® format and included in the GIS. These maps and databases will be completed in the next year and made available through the public access GIS and also as digital products available through our web site. Thirty of the detailed Faribault gold district maps have been digitized and checked by Gayle Chapman. Megan Surrette, a summer student, has converted many of these maps into ARC/INFO® format and put them into the GIS.

1:10 000 Digital Elevation Model and Watershed Project

This project was initiated with the cooperation of the Nova Scotia Geomatics Centre (NSGC), Department of

Agriculture and Marketing, DNR Forestry Division and DNR Wildlife Division. Krista Fraser developed a GIS application to produce hydrologically correct Digital Elevation Models (DEMs) from the 1:10 000 topographic base maps and then produce watershed maps. In April 1999 Krista left the department and joined NSGC, where she has been overseeing the continuation of this project. Development of the DEMs was completed in December 1999. These images will be added to the public access GIS, and the digital data will be available through NSGC. Development of the watersheds from the DEMs will begin in January 2000.

Internet Map Projects

Jeff Poole is currently investigating the feasibility of creating an internet map server that will allow our clients to view, query, plot and download our digital maps and databases over the internet. Several prototype applications have already been developed internally. Over the next year Jeff will be committing the majority of his development time to producing an internet application that will be available to the general public. It is planned that the initial deployment of this application will be in the summer of 2000.

Y2K Project

Brian Fisher worked on Y2K-related issues to ensure that the UNIX SUN workstation, GIS software, hardware, and all the GIS databases are Y2K ready. All hardware and software were upgraded to ensure compliance. The GIS databases were thoroughly checked and found to be fully compliant. The Digital Information Services group experienced no Y2K-related problems entering the new year and look forward to continuing to serve its clientele in the year 2000.

Web Site Development

NovaScan

NovaScan is the bibliographic geoscience database on Nova Scotia and its offshore regions. As of December 31, 1999, the database contained 14 515 DNR records, consisting of 6411 mineral exploration assessment reports, 3415 publications, 2606 open files, 1156 journal literature references, 756 theses, 155 contribution series, 12 digital publications, and 4 outside publications. NovaScan was updated with the following 238 new records this year: 219 assessment reports, 15 open files and 4 contribution series. Custom searches of the NovaScan database for clients will be done on request.

This year 129 assessment reports were publicly released from confidential status. Each month, a list of open assessment reports was generated from NovaScan, distributed to the DNR Library, the Core Library in Stellarton, and to the three Regional Geologists in Coxheath, Bible Hill and Bridgewater, as well as posted on the MEB web site. Quarterly reports were produced and published in the *Nova Scotia Minerals Update* newsletter, and on the web site. The following assessment report index was released during this calendar year: *NTS Location, Author and Citation Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports 1996-1998, Open File Report ME 1999-1. NTS Location, Author and Citation Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports 1996-1999, Open File Report ME 2000-1,* will be released in January 2000.

In order to provide better service to our staff and clients by allowing internet access to and searching of the NovaScan database, two independent projects were carried out in 1999. The first project involved downloading the database into the branch GIS and creating geographic boundaries for all NovaScan records. When complete, the user will be able to search the NovaScan database through the public access GIS, and also on the internet. Completion of this project should take place in year 2000. The second project involved downloading and converting the NovaScan records into standard library MARC format, so that they could be loaded into the Provincial Library's internet-accessible *NcompasS®* catalogue database. The catalogue can be accessed at the following address: http://ncompass.library.ns.ca. After selecting your language of choice (English/French), select Nova Scotia Department of Natural Resources from the available catalogue listings, and you will then be able to search the NovaScan records.

Publications

The following publications are available on our web site. An asterisk indicates that the publication was posted to the web site during 1999.

Bulletin

***Bulletin ME 1, 1962** Port Hawkesbury Project - Geology, Geochemistry and Groundwater Investigations of Southwest Inverness and Richmond Counties, Nova Scotia.

Contribution Series

CS ME 1998-1 Gold and Base Metals Highlight Exploration in 1997, by Paul D. McCulloch (presented at the 1998 PDAC).

Economic Geology Series

***EGS ME 1975-1** Iron Deposits of Nova Scotia.

***EGS ME 1990-1** Diatomaceous Earth Occurrences in Nova Scotia.

EGS ME 1996-1 Building Stone in Nova Scotia.

Information Circulars

***IC ME 1, 1988 (revised 1993)** Directory of Goods and Services for Exploration Companies.

***IC ME 2, 1986** Mineral Rights, Landowners, and Mineral Exploration.

***IC ME 3, 1986** A Walking Tour of Rocks, Minerals, and Building Stones in Downtown Halifax.

***IC ME 4, 1988** Nova Scotia Gold.

***IC ME 7, 1986** A Walking Tour of Rocks, Minerals and Landforms of Point Pleasant Park.

***IC ME 9, 1987** A Walking Tour of Rocks, Minerals and Landforms of Peggys Cove.

IC ME 10, 1987 A Walking Tour of Rocks, Minerals and Building Stones of Spring Garden Road, Halifax.

***IC ME 11, 1987** A Walking Tour of Rocks, Minerals and Landforms of Victoria Park, Truro.

IC ME 12, 1993 Building Stone in Nova Scotia.

IC ME 13, 1993 Limestone and Dolomite in Nova Scotia.

IC ME 14, 1991 Silica in Nova Scotia.

IC ME 15, 1991 Barite, Celestite and Fluorite in Nova Scotia.

IC ME 16, 1993 Gypsum and Anhydrite in Nova Scotia.

IC ME 18, 1993 Peat Moss in Nova Scotia.

IC ME 19, 1993 Salt in Nova Scotia.

IC ME 20, 1993 Aggregate in Nova Scotia.

IC ME 22, 1988 Land Use Policy Development Project.

***IC ME 23, 1981** Petroleum Resources Offshore and Onshore Nova Scotia, Canada.

IC ME 24, 1991 Industrial Minerals in Nova Scotia.

***IC ME 25, 1993** One of the Greatest Treasures: The Geology and History of Coal in Nova Scotia

***IC ME 26 (revised March 1993)** The Cohasset Project.

IC ME 27, 1992 GEOFACTS: Using Digital Sound in Marine Geoscience.

IC ME 28, 1992 GEOFACTS: Hydrocarbon Charge Modelling.

IC ME 29, 1992 GEOFACTS: Canada's Dynamic Coastline.

IC ME 30, 1992 GEOFACTS: Modelling the Development of Rifted Continental Margins -"Time Travel by Computer".

IC ME 31, 1992 GEOFACTS: Anhydrite in Nova Scotia.

IC ME 32, 1992 GEOFACTS: Gypsum in Nova Scotia.

IC ME 33, 1992 GEOFACTS: Salt in Nova Scotia.

IC ME 34, 1992 GEOFACTS: Industrial Minerals in Nova Scotia.

***IC ME 36, 1993** Metalliferous Environments of Nova Scotia - Base Metals (Summary).

***IC ME 37, 1993** Properties Available For Option In Nova Scotia, March 1993.

***IC ME 38, 1994** Properties Available For Option In Nova Scotia, March 1994.

***IC ME 39, 1994** Petroleum Resources, Offshore and Onshore, Nova Scotia, Canada - We're Worth Exploring!

***IC ME 41, 1993** Career Choices in the Petroleum Industry.

***IC ME 42, 1995** A Sign to Watch Your Step (This information brochure describes hazards associated with abandoned mine sites).

***IC ME 45, 1996** Take Advantage of Mineral Exploration and Development in Nova Scotia.

***IC ME 46, 1996** Copper Deposits in the Carboniferous Rocks of Northern Nova Scotia.

***IC ME 47, 1996** Vein and Breccia Deposits of Fe-Cu-Co-Ni-Ba-Au Associated with the Cobequid-Chedabucto Fault Zone, Nova Scotia.

***IC ME 49, 1996** Ni-Cu-Co Associated with Mafic and Ultramafic Rocks of Cape Breton Island.

***IC ME 50, 1996** Carbonate-Hosted Zn-Pb-Ba-Ag-Cu Deposits in the Lower Carboniferous of Nova Scotia: the Irish Connection.

***IC ME 51, 1996** Gold Deposits in the Meguma Group of Nova Scotia.

***IC ME 52, 1996** Geology and Mineral Deposits of Nova Scotia.

***IC ME 53, 1998** Secondary Processing of Industrial Minerals in Nova Scotia.

***IC ME 54, 1997** Properties Available for Option in Nova Scotia, January 1997.

IC ME 55, 1997 Safe Work Methods Handbook, August 1997.

IC ME 56, 1997 A User's Guide to the 'One Window' Process for Mine Development Approvals.

IC ME 57, 1998 Properties for Option in Nova Scotia, January 1998.

IC ME 58, 1998 A Guide to Mineral Exploration Legislation in Nova Scotia.

***IC ME 59, 1999** Properties for Option in Nova Scotia, January 1999.

Information Series

IS ME 10, 1986 Petroleum Wells, and Drillholes with Petroleum Significance Onshore Nova Scotia.

***IS ME 13, 1987** Gold in Nova Scotia.

IS ME 19, 1987 Nova Scotia Dimension Stone for Designers, Developers, Quarriers.

IS ME 22, 1993 Metalliferous Environments of Nova Scotia - Base Metals (Main Paper).

IS ME 23, 1997 Abandoned Mine Openings Hazards and Remediation Handbook.

***IS ME 24, 1996** Twentieth Annual Review of Activities, 1996.

Open File Reports

OFR ME 1997-6 Report on a Diamond-Drilling Program, Mile 16 East Road and MacKenzie Road South, Victoria County, Nova Scotia.

OFR ME 1997-7 Report on Diamond-Drilling and Geological Investigations of the Steves Road Lead-Gold Occurrence, North Beaverbank, Hants County, Nova Scotia.

***OFR ME 1997-8** First Annual Nova Scotia Department of Natural Resources/Geological Survey of Canada (Atlantic) Joint Work Plan for Geoscience in Nova Scotia, 1997-1998.

OFR ME 1998-2 NTS Location Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, Contribution Series, Digital Geoscience Data Products, Open Files and Publications, 1996 and 1997.

OFR ME 1998-3 Author Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, Contribution Series, Digital Geoscience Data Products, Open Files and Publications, 1996 and 1997.

OFR ME 1998-4 Petroleum Occurrence in Drillholes from the Pictou Coalfield.

***OFR ME 1998-5** Classic Carboniferous Sections of the Minas and Cumberland Basins in Nova Scotia: with Special Reference to Organic Deposits.

***OFR ME 1999-1** NTS Location, Author and Citation Index Map Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, 1996-1998.

Reports

***Report ME 1998-2** Mining Matters for Nova Scotia '98: Opportunities for Economic Development.

***Report ME 1999-1** Minerals and Energy Branch Report of Activities, 1998.

***Report ME 1999-2** Mining Matters for Nova Scotia '99: Opportunities for Economic Development.

Mesozoic Stratigraphy and Kaolin Exploration in the Sibley Road Area (NTS 11E/03), Halifax County

M. X. Gillis[1] *and R. R. Stea*

Introduction

Geological mapping of the Musquodoboit Valley by the Nova Scotia Department of Natural Resources and Geological Survey of Canada has led to the recognition that vast hidden valleys, filled with up to 200 m of Cretaceous sediment, are buried under a veneer of glacial deposits (Lin, 1970; Fowler, 1972; Stea and Fowler, 1981; Dickie, 1986; Stea *et al.*, 1996; Finck *et al.*, 1998). In 1996, Kaoclay Resources Inc. (Kaoclay) was formed to explore the Cretaceous basins of Nova Scotia for industrial minerals, including paper-grade kaolin.

Kaoclay's main area of interest in Nova Scotia is in the Musquodoboit Valley where Cretaceous sediments covering an area of approximately 42 km² have been delineated through seismic surveys and drilling (Stea *et al.*, 1996). The company has identified several areas of interest within this area and has chosen for its initial detailed evaluation an area of approximately 3 km² in the Sibley Road area, located just west of the village of Middle Musquodoboit (Fig. 1). This area of Mesozoic sediments straddles a proposed fault in the Musquodoboit Valley termed the Rutherford Road fault (Stea and Pullan, 1998), south of which lies the thickest Mesozoic section. Mesozoic-Cenozoic faulting has created a trough in which Cretaceous sediments have been preserved below regional base-levels (Stea and Pullan, 1998).

Initial results from this detailed exploration program were very encouraging and resulted in the identification of a consistent stratigraphic package, referred to by Kaoclay geologists as the Sibley Road unit. This unit includes light-grey kaolinitic clay and sand of economic interest. Beneficiation of initial test pit and drill core samples returned encouraging results with a number of samples meeting brightness specifications established by the paper industry.

A systematic grid, referred to as the Sibley Road grid, was established over this area with the initial lines spaced at 200 m for a total of 21 km of grid lines (Fig. 2). A reflection seismic survey was completed over the entire grid area in January 1998, and a drilling program was carried out at 200 m intervals along the grid lines at the end of May 1998. This drilling program identified an area of 3.2 km² underlain by the Sibley Road unit.

Based on drilling and seismic results from the 200 m grid, several areas were selected for a more detailed drilling program at 100 m intervals. This detailed grid-drilling program was carried out over an area of approximately 1 km² and resulted in a more detailed understanding of the stratigraphy underlying the Sibley Road area.

Stratigraphy

A coherent stratigraphic picture has emerged as a result of the drilling program. The entire area is covered by glacial till, varying in thickness from 1 m to 10 m. The till is underlain by Cretaceous sediments including the Sibley Road unit, which can be subdivided into the lower, middle and upper units.

The lower Sibley Road unit consists of interbedded medium- and light-grey clay, grey-brown clay, lignitic clay and minor silica sand intervals. Although this lower unit is commonly found in the northern Sibley Road area, in the vicinity of the Rifle Range Road, it is absent south of this area in the vicinity of Highway 224 (Fig. 2).

The middle Sibley Road unit consists of red, black and dark grey clay with varying amounts of charcoal and lignite fragments. This unit has an average thickness of approximately 3 m and is a distinct marker unit separating the upper and lower Sibley Road units. The middle unit is crucial in our understanding of the stratigraphy of the Sibley Road unit, although it is not always present in the stratigraphic sequence. It is analogous to the Middle Member of the Chaswood Formation, a much thicker organic unit that serves to divide the Mesozoic sequence south of the Rutherford Road fault (Stea *et al.*, 1997; Stea and Pullan, 1998).

The upper Sibley Road unit can be identified by a number of distinct features, including the presence of light-grey (nearly white) and minor cream-coloured

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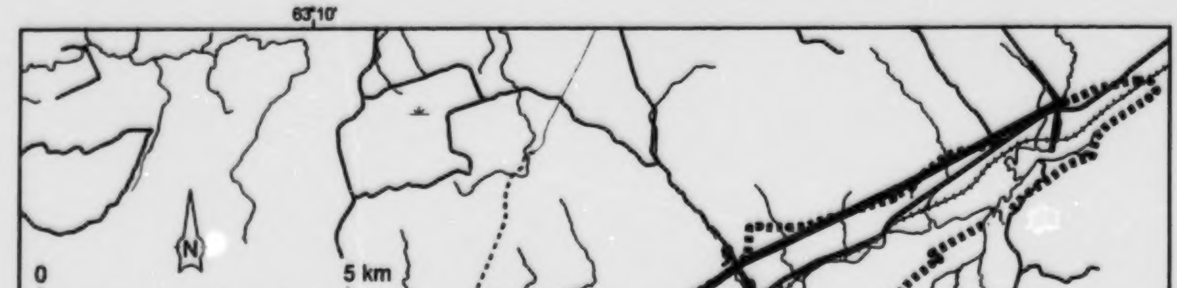

Figure 1. Location of the Elmsvale Basin (Chaswood Formation-Early Cretaceous) in the Musquodoboit Valley.

clay, massive to mottled purple and pink fine-grained clay, and fine to coarse, poorly-sorted light-grey silica sand which is commonly micaceous and contains clay balls (Fig. 3). This unit also has small amounts of red and yellow, ochre-stained clay and sand, and red-brown clay. Beds of dark grey to black lignitic clay are also found in the upper Sibley Road unit but are not always present in drillhole intersections. Drill data from the 200 m grid drilling program indicate that the upper Sibley Road unit varies in thickness from 2.2 to 68.6 m with an average thickness of 36.2 m. The upper Sibley Road unit appears to have the greatest potential for hosting large volume, commercial-grade clay deposits, based on exploration and analytical testing to date.

In 31 of the 72 holes drilled as part of the 200 m drilling program, the upper Sibley Road unit is overlain by darker coloured clay and sand of the middle member of the Chaswood Formation where Cretaceous sediments are thickest. Cretaceous sediments were intersected in all but 12 of the 153 holes drilled in the Sibley Road area as part of the initial exploration program and the 200 m grid drilling program. All 12 of these holes were drilled along the edge of the Cretaceous basin and have helped to define the extent of Cretaceous sediments in this area.

In 1998, Kaoclay carried out a program of bulk sampling in the Sibley Road area to acquire sufficient material for beneficiation tests. A bucket auger was used to extract large volumes of samples from the upper Sibley Road unit. Approximately 45-50 tonnes of material were taken from carefully selected locations to ensure that samples representative of the entire deposit were collected.

Of the 45 to 50 tonnes of sample material taken from the upper Sibley Road unit, approximately 30 tonnes (185 samples) have been sent to Kaoclay's laboratory in Eatonton, Georgia. This material has been subdivided into seven economic categories (K-1 to K-7), based on texture and amount of impurities. These include five primary clay types with two variants based on the amount of sand; for example, K-2 and K-7 have a

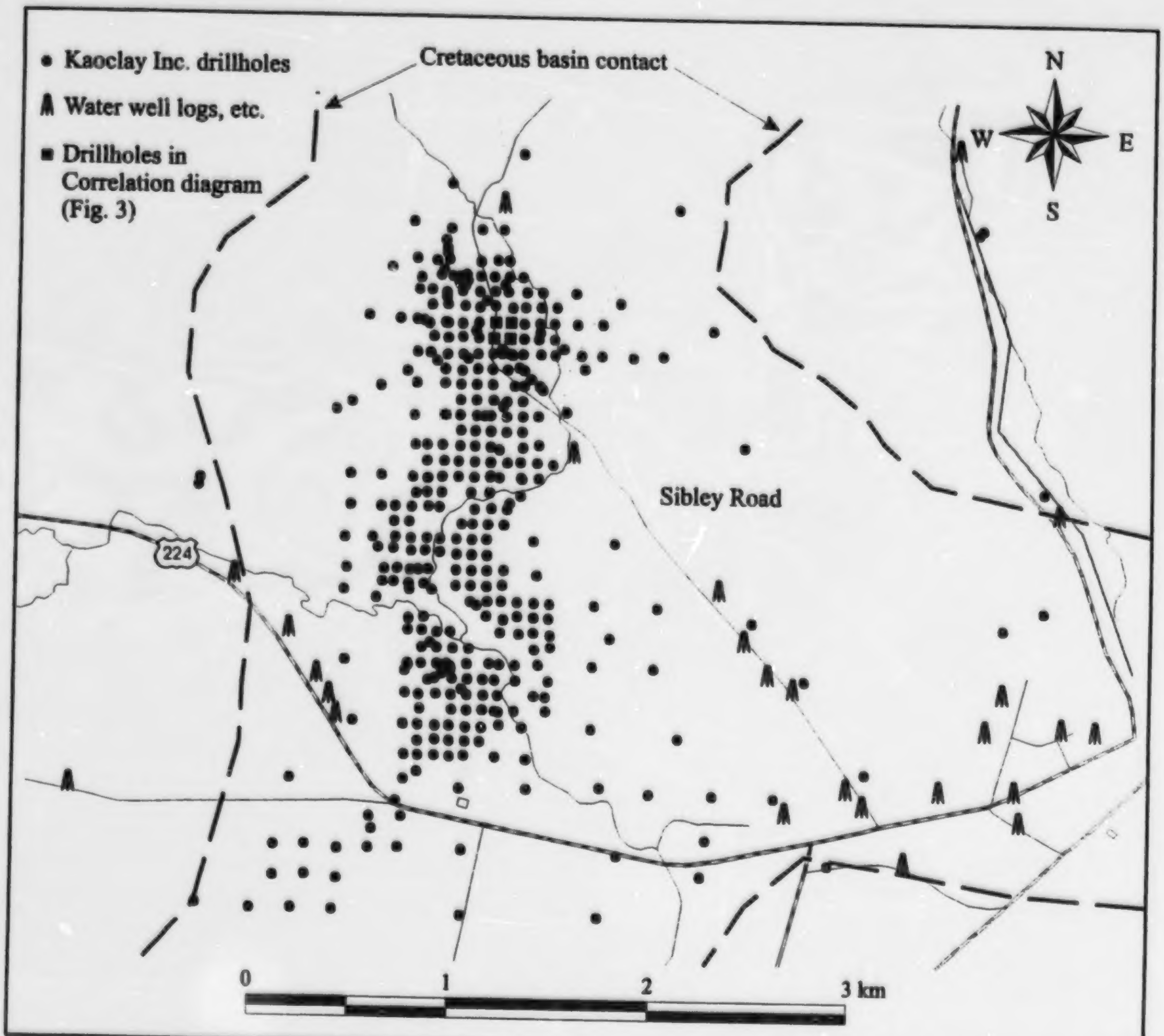

Figure 2. Detailed map showing the Sibley Road drill grid area and locations of the type drillholes of the upper Sibley Road unit.

similar clay type as K-1 and K-6, but have a higher grit content. These categories were determined by colour, the amount of visible oxidization, and grit content (the amount of sand versus clay) and represent discrete stratigraphic intervals within the upper Sibley Road unit (Fig. 3). The seven economic clay categories may be described as follows:

K-1 - light grey clay, minor yellow iron staining
K-2 - light grey silty clay, micaceous, minor yellow iron staining
K-3 - clay and silty clay, light grey with moderate yellow iron staining
K-4 - clay, pink and light to medium purple in color
K-5 - clay and silty clay, iron yellow and light to medium purple in color
K-6 - sand, minor clay and clay lenses, light grey, micaceous with minor yellow iron staining
K-7 - sand, minor clay, light grey with minor yellow iron staining

Approximately 80% of the upper Sibley Road unit has been classified as categories K-1 through K-7. The portion of this 80% that represents economically viable kaolin once the grit has been removed has yet to be determined. Of the seven categories, K-1, K-2, K-6 and K-7 have the highest potential for making kaolin product. The sand-dominated units (K-6 and K-7) have

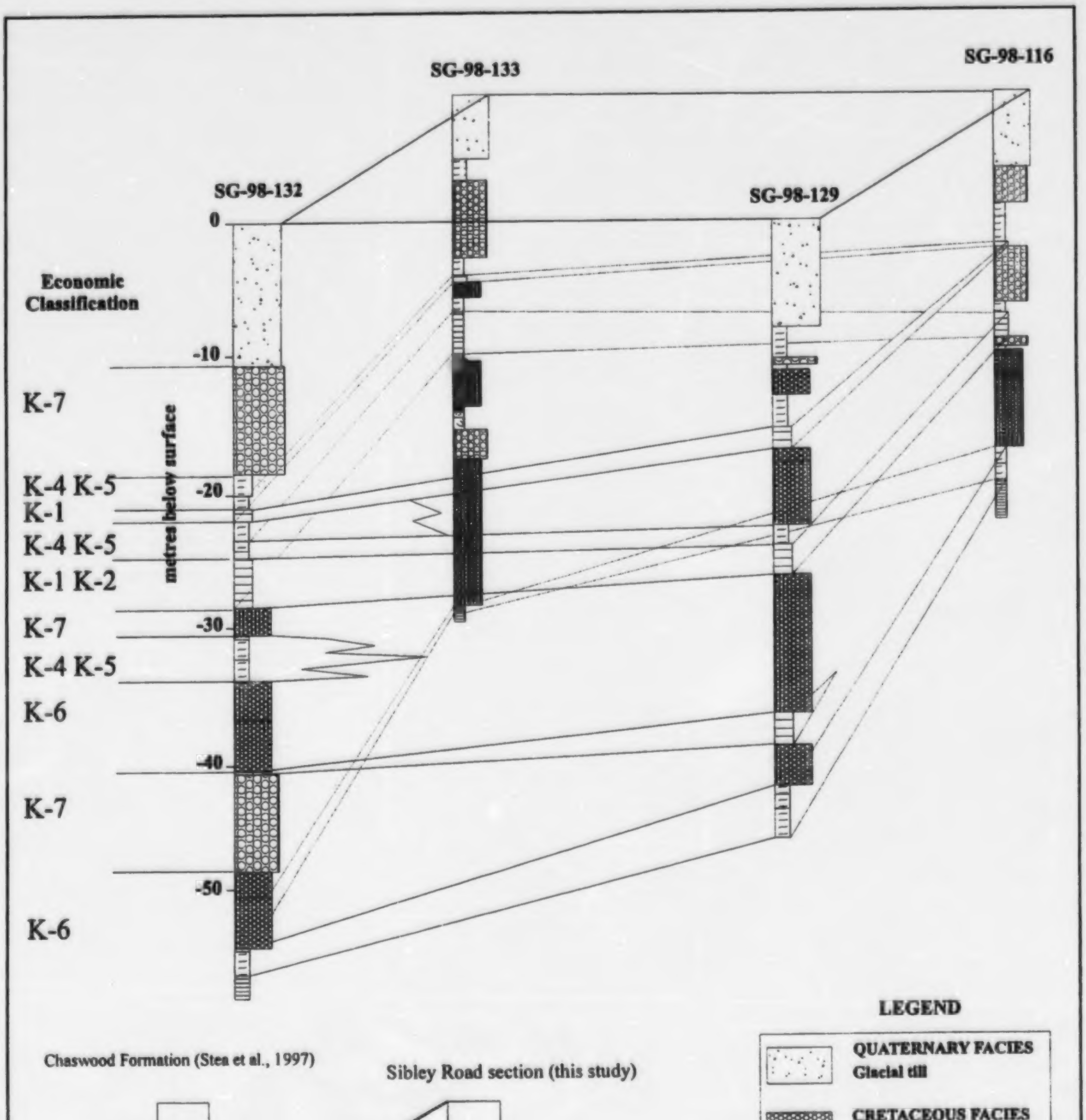

Figure 3. Stratigraphy of the upper Sibley Road unit in the Sibley Road drill grid and correlation of economic units.

produced high-brightness kaolin but the clay yields are lower (Finck *et al*, 1998). Figure 3 is a correlation of the K units and sediment lithofacies from four representative drillholes from the upper Sibley Road unit on the Sibley Road grid. The K-1 and K-2 units are roughly 2 m thick in this section and, if consistent within a 100 m by 100 m area, would represent approximately 20,000 m^3 of raw clay or 42,000 tonnes. Across the entire 3 km^3 grid in the Sibley Road area the total tonnage of clay units K-1 to K-7 is estimated to be 172 million tonnes. To confirm correlation of individual clay layers and to test the consistency of the clay layers, drilling at 50 m centres is now being undertaken.

Kaolin Beneficiation Trials

To date, Kaoclay's technical consultants have developed effective lab-scale beneficiation processes for all of the clay units that achieved paper-grade specifications for brightness. Pilot plant testing of selected samples is required in order to verify the lab-scale work and to determine the economic viability of the beneficiation processes developed for the various clay types. Detailed processing results of kaolin samples from other areas in the Musquodoboit Valley are available (Finck *et al.*, 1998) and have shown that production of a variety of filler-grade and calcined-coater grade kaolin products is possible.

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C-horizon Till and Stream Sediment Geochemical Survey, Kennedys Big Brook (NTS 11F/14), Inverness County

T. A. Goodwin

Introduction

A till and stream sediment sampling program was conducted by the Nova Scotia Department of Natural Resources in the Kennedys Big Brook area of Cape Breton Island in the fall of 1999 (Fig. 1). The survey is a supplementary component of the Marble Mountain - Kennedys Big Brook mineral resource evaluation and geological mapping program which is described in more detail by DeMont *et al.* (this volume).

Preliminary results of the mineral resource evaluation suggest that there is potential in the North Mountain area, and in particular along the Kennedys Big Brook valley, for the occurrence of a structurally controlled, hydrothermal gold deposit. The geochemical survey was conducted to verify this mineral potential in the project area and to assess the effectiveness of till and stream sediments as sample media in this environment.

Bedrock Geology

Regionally, the project area consists of a wedge of northwest-trending, undivided Proterozoic rocks of the George River Group consisting of calc-silicates, marble and quartzite (Keppie, 1979). These rocks are preserved within younger Hadrynian granitoids oriented northeast-southwest, and collectively they form the North Mountain.

Kelley (1957, 1968) mapped the Whycocomagh area and results of his mapping indicated that the area is underlain by pre-Carboniferous quartz monzonite and granodiorite to the north and undivided Precambrian schist, limestone, quartzite with minor volcanics and greywacke of the George River Group to the south. Kelley (1957) also noted a pyrite occurrence along Kennedys Big Brook (formerly Campbell Brook). Detailed mapping by Milligan (1970) indicated that the

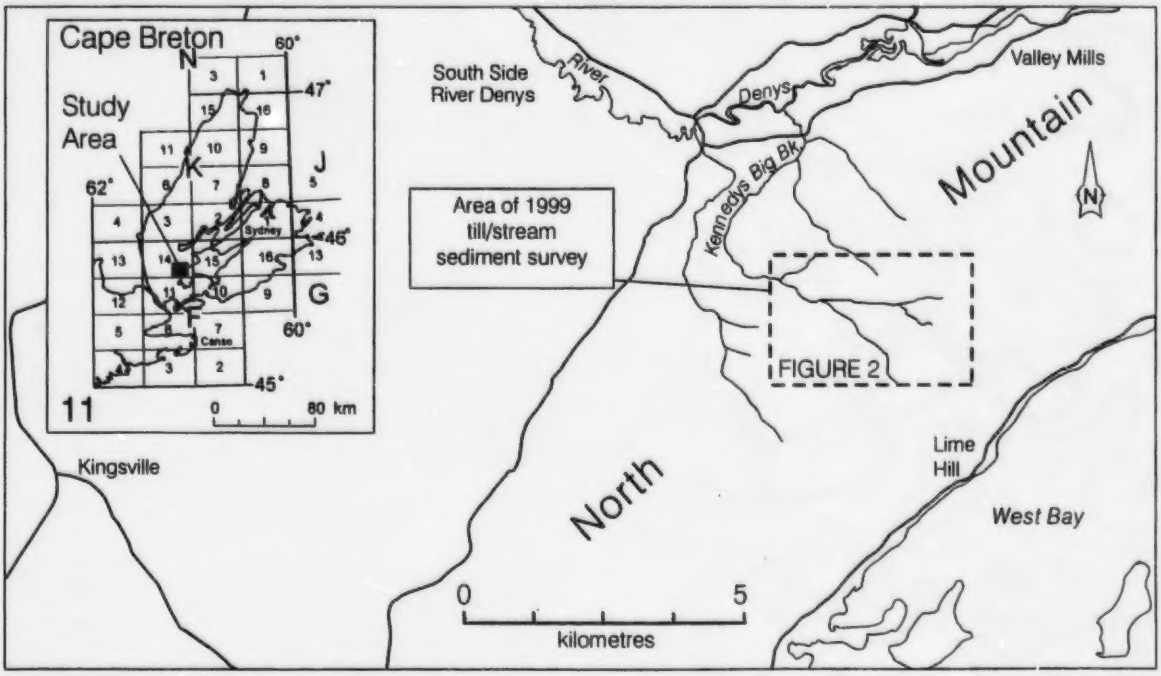

Figure 1. Till and stream sediment geochemical survey area, Kennedys Big Brook, Cape Breton Island.

local bedrock geology is dominated by the Archean George River Group, comprising slate and variably coloured limestone in fault contact with Paleozoic granite. Recent mapping by Lynch and Brisson (1994) indicated that the geology of the study area is dominated by coarse-grained granite and porphyritic granite of uncertain age (Proterozoic to Devonian?) in fault contact with Proterozoic schist, metabasalt and wacke of the George River Group.

The pyrite occurrence along Kennedys Big Brook (Kelley, 1957) is spatially associated with an inferred northwest-trending structure. The structure, noted in a few poorly exposed outcrops, is characterized by a penetrative deformation fabric and variable carbonate-sulphide-hematite alteration.

The project area is characterized by variable topography. Elevation changes rapidly from a high of 240 m above sea level (ASL) in the granites to a low of 100 m ASL in the incised valleys of George River Group rocks. The vegetation is dominated by mature mixed woods with local clear-cuts and replants.

Surficial Geology

The surficial geology of North Mountain is characterized by a veneer of till over bedrock (Stea *et al.*, 1992) with colluvial deposits in incised stream valleys. The top of North Mountain is characterized by drumlins oriented northwest-southeast. Quantitative ice flow indicators measured along the north shore of West Bay indicate that ice advanced toward the northwest (Stea *et al.*, 1992).

Grant (1988) characterized the surficial geology as bedrock terrain covered by a thin mantle of till. Post-glacial colluvium locally overlies the till in steeply incised brook valleys. Ice flow indicators mapped on the northern shore of West Bay indicate ice flowed to the north-northwest. The surficial geology of the area observed during the current till and stream sediment sampling program is characterized by more areally extensive till and less colluvium than mapped by Grant (1988).

The carbonate bedrock is characterized by numerous rills, possibly the result of dissolution by excess water associated with deglaciation. Locally, the coarse-grained granite is highly sheared and, as a result, preservation of glacial striations is limited to one outcrop of polished black shale. Two sets of striations were mapped during the geochemical survey; the older was 098°-278° with a younger set measuring 132°-312°. A sense of direction could not be established.

Previous Geochemical Sampling Programs

Government Surveys

The Nova Scotia Department of Mines and Energy completed regional stream sediment surveys in 1973-1978, 1981-1983 and 1986-1987. An overview of these programs is summarized in Rogers and Lombard (1990). Gold, however, was analyzed only in the 1986-1987 survey both in the <63 µm fraction and in the heavy mineral concentrates (HMC). No samples were collected in the immediate area of the 1999 survey.

The mineralized outcrop of Precambrian George River Group rocks noted by Kelley (1957) is included in the NSDNR Mineral Occurrence Database as Occurrence Number F14-036. As part of the Mineral Inventory study, the mineralized outcrop was sampled by staff geologists. Analytical results indicate the rocks are characterized by anomalous Ag-As-Sb and elevated Au. A second occurrence, Occurrence Number F14-050, consists of an arsenopyrite-bearing quartzite boulder located along a tributary of Kennedys Big Brook.

Industry Surveys

A stream silt geochemical survey was conducted by LURA Corporation Limited during the early 1960s (Hudgins, 1962). A number of base metal anomalies were identified and subsequent soil geochemical and self potential (SP) geophysical surveys were completed.

During the 1987 field season, Inco Gold conducted a regional stream sediment sampling and geological mapping program for gold over parts of Cape Breton Island (Booth, 1988). Panned heavy mineral concentrates recovered from stream sediments collected from Kennedys Big Brook returned anomalous gold levels (up to 1590 ppb) and several grains of visible gold were found in a number of samples. Pyritized boulders and outcrops were mapped and sampled along Kennedys Big Brook. Geochemical analysis of several of these rock samples revealed anomalous Au-Ag-As.

1999 Geochemical Program

Introduction

Orientation sampling by the Geological Survey of Canada (McClenaghan *et al.*, 1992), approximately

50 km east of Kennedys Big Brook, indicated that the best and most cost-effective sample medium to collect and analyze was the C-horizon till (<63 µm fraction). As a result of their findings, the <63 µm fraction of C-horizon till was used as the preferred sample medium for this survey.

As part of the till sampling program, several roadside profiles were cut in order to examine till colour, matrix composition, and clast type and content. Till lines were subsequently oriented to maximize geochemical response from a mineralized source, taking into account orientation of the structure, lithologic contacts, ice flow direction(s), size of expected dispersal pattern, sample medium and analytical methodology.

Stream sediments (<63 µm) were also collected in order to assess the mineral potential of the Kennedys Big Brook catchment area. Sample sites were chosen from streams that crossed the inferred mineralized structures.

Sampling Methods

A total of 24 C-horizon till samples were collected by auger from an average depth of 60 cm. Approximately 500 g of till were collected at each sample site and placed in Kraft sample bags. Samples were collected every 50-100 m along four lines spaced 200-500 m apart. Lines were oriented 040°-220° (declination 22.5° W), and control along the lines was maintained by a combination of pace and compass and use of 1:10 000 scale colour air photos. Sample sites were marked on the air photos and UTM co-ordinates (NAD-27) were captured by GPS (Garmin 12).

In addition to the 24 till samples, five stream sediment samples were collected by shovel from the active flow of the stream. Approximately 2 kg of stream sediment were collected at each sample site and placed into 6 mm plastic sample bags. Each sample was a composite sample, that is, the 2 kg of sediment were collected from 5-7 sites along a 10-25 m length of stream. Samples were collected behind natural traps, generally boulders, and passed through a <0.85 mm sieve in order to maximize the amount of <63 µm material being collected. The <0.85 mm material was subsequently collected in a plastic gold pan. Excess sand grains remaining on the shovel were washed into the gold pan after each shovel full of stream sediment. Excess water in the plastic bags was carefully decanted the following day.

Similar to the till sampling, the stream sediment sample sites were marked on air photos and UTM co-ordinates (NAD-27) were captured by GPS (Garmin 12). Field observations were recorded at each till and stream sediment sample site.

Analytical Methods

A total of 29 till samples (24 collected plus 5 analytical control samples) and 7 stream sediment samples (5 collected plus 2 analytical control samples) were sent to Intertek Testing Services (Bondar Clegg) in Val d'Or, Quebec. All till and stream sediment samples were dried and sieved to obtain the <63 µm size fraction. A 30 g sample was analyzed for gold by Fire Assay/Atomic Absorption (FA/AA) and a 1 g sample was analyzed for multi-element geochemistry by Inductively Coupled Plasma/Atomic Emission Spectroscopy (ICP/AES) following an aqua regia digestion. A summary of the elements analyzed, extraction methods, analytical methods, and lower and upper detection limits is presented in Table 1.

Quality Assurance/Quality Control

A number of quality assurance/quality control measures were incorporated into the sampling protocol to ensure confidence in the quality of the data.

In the field, all work was planned and executed by the Project Geochemist for DNR. At two till sites and one stream sediment site, field duplicates were collected in order to ascertain site variance. With the exception of one till sample, all till and stream sediment samples collected in the field were of excellent quality.

For till and stream sediment samples submitted to the laboratory, a number of controls were in place in order to test analytical accuracy and precision (Table 2). A low level certified gold standard and a high level internal gold standard were submitted with the till and stream sediment samples. An analytical replicate was submitted with the till samples, but not with the stream sediment samples because only a few stream sediment samples were submitted for analysis.

Results

Analytical results for both the low-level and high-level gold standards and the analytical replicates were within acceptable limits. As a result, the data are deemed to be of good quality. Results for field duplicates indicate the samples are highly representative of the area they were collected from.

Table 1. Analytical methods for <63 µm till and stream sediment samples.

Element	Extraction Method	Analytical Method	Lr. Detection Limit	Up. Detection Limit
Au (30 g)	fire assay	AA	5 ppb	999 999 ppb
Ag	aqua regia	ICP-AES	0.2 ppm	200 ppm
Cu	aqua regia	ICP-AES	1 ppm	10 000 ppm
Pb	aqua regia	ICP-AES	2 ppm	10 000 ppm
Zn	aqua regia	ICP-AES	1 ppm	10 000 ppm
Mo	aqua regia	ICP-AES	1 ppm	10 000 ppm
Ni	aqua regia	ICP-AES	1 ppm	20 000 ppm
Co	aqua regia	ICP-AES	1 ppm	20 000 ppm
Cd	aqua regia	ICP-AES	0.2 ppm	2000 ppm
Bi	aqua regia	ICP-AES	5 ppm	2000 ppm
As	aqua regia	ICP-AES	5 ppm	10000 ppm
Sb	aqua regia	ICP-AES	5 ppm	2000 ppm
Fe (total)	aqua regia	ICP-AES	0.01%	10.00%
Mn	aqua regia	ICP-AES	1 ppm	20 000 ppm
Te	aqua regia	ICP-AES	10 ppm	2000 ppm
Ba	aqua regia	ICP-AES	1 ppm	2000 ppm
Cr	aqua regia	ICP-AES	1 ppm	20 000 ppm
V	aqua regia	ICP-AES	1 ppm	20 000 ppm
Sn	aqua regia	ICP-AES	20 ppm	2000 ppm
W	aqua regia	ICP-AES	20 ppm	2000 ppm
La	aqua regia	ICP-AES	1 ppm	2000 ppm
Al	aqua regia	ICP-AES	0.01%	10.00%
Mg	aqua regia	ICP-AES	0.01%	10.00%
Ca	aqua regia	ICP-AES	0.01%	10.00%
Na	aqua regia	ICP-AES	0.01%	10.00%
K	aqua regia	ICP-AES	0.01%	10.00%
Sr	aqua regia	ICP-AES	1 ppm	2000 ppm
Y	aqua regia	ICP-AES	1 ppm	2000 ppm
Ga	aqua regia	ICP-AES	1 ppm	10 000 ppm
Li	aqua regia	ICP-AES	1 ppm	20 000 ppm
Nb	aqua regia	ICP-AES	1 ppm	10 000 ppm
Sc	aqua regia	ICP-AES	5 ppm	2000 ppm
Ta	aqua regia	ICP-AES	10 ppm	1000 ppm
Ti	aqua regia	ICP-AES	0.01%	5.0%
Zr	aqua regia	ICP-AES	1 ppm	5000 ppm
S	aqua regia	ICP-AES	0.01%	10.00%
Hg*	aqua regia	Cold Vapour	1 ppm	50 ppm

*Only one sample was analyzed for Hg, stream sediment sample NSSS-003. This sample was the only sample air dried.

Only two till samples returned gold levels above the lower detection limit of 5 ppb. The two samples returned gold levels of 7 ppb and 10 ppb (Fig. 2). The till sample with the highest gold concentration also returned the highest levels of As-Sb-Ag-Ba-Pb-Cu-Cd. Tills were not analyzed for Hg.

With the exception of one sample, all stream sediment samples returned elevated gold concentrations (32 ppb-483 ppb) in the <63 µm fraction (Fig. 2). A stream sediment sample collected near the previously mentioned mineralized bedrock outcrop in the stream returned 154 ppb Au and anomalous As-Sb-Ba-Cu-Cd.

Table 2. Quality control samples for <63 µm till and stream sediment samples.

Survey	Control	Sample #	Description
till	field duplicate	NST-002	filed duplicate of NST-001
till	field duplicate	NST-022	filed duplicate of NST-021
till	standard	NST-010	high level internal gold standard
till	standard	NST-028	high level internal gold standard
till	standard	NST-020	certified low level internal gold standard
till	standard	NST-029	certified low level internal gold standard
till	analytical replicate	NST-023	analytical replicate of NST-013
stream	field duplicate	NSSS-002	filed duplicate of NSSS-001
stream	standard	NSSS-006	certified low level internal gold standard
stream	standard	NSSS-007	high level internal gold standard

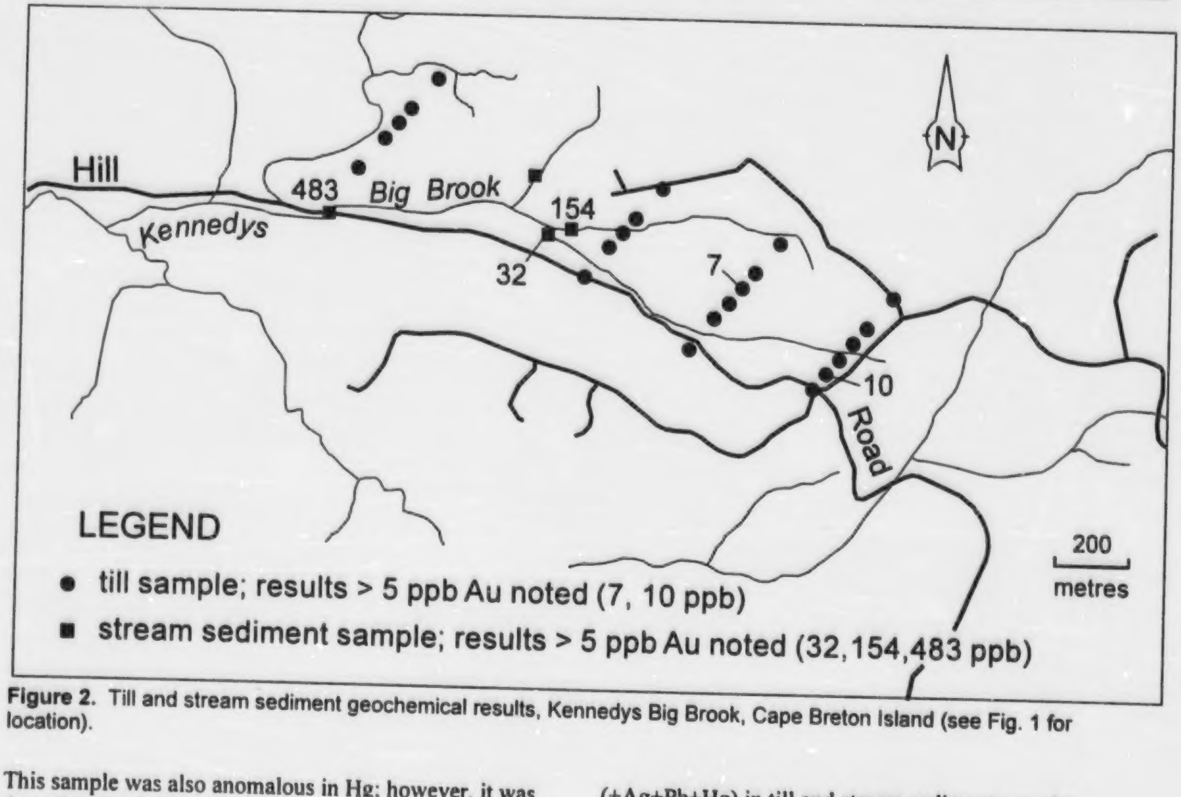
Hill
483
Big Brook
154
Kennedys
32
7
10
Road
N
200
metres
LEGEND
● till sample; results > 5 ppb Au noted (7, 10 ppb)
■ stream sediment sample; results > 5 ppb Au noted (32,154,483 ppb)

Figure 2. Till and stream sediment geochemical results, Kennedys Big Brook, Cape Breton Island (see Fig. 1 for location).

This sample was also anomalous in Hg; however, it was the only sample from the survey analyzed for Hg. A field duplicate pair collected approximately 500 m downstream returned gold levels of 135 ppb and 483 ppb.

Interpretation

Elevated concentrations of Au-As-Sb-Ba-Cu-Cd (±Ag±Pb±Hg) in till and stream sediment samples indicate that a possible mineralized source may exist on the property. This geochemical association is typical of an epithermal deposit and is consistent with previous sampling of the mineralized outcrop exposed along Kennedys Big Brook by the government and Inco surveys. The anomalous till sample and the mineralized outcrop both occur along the projected trace of an inferred northwest-southeast structure.

The lack of geochemical gold response from the majority of the till samples may be, at least in part, explained by the widely spaced survey lines. One or several of the lines may not have crossed the inferred mineralized structure.

Conclusions

Anomalous gold concentrations in till and stream sediments indicate that gold may be present in bedrock on the Kennedys Big Brook property, and that the potential mineralized zone is probably associated with inferred structures. Results of the survey indicate both till and stream sediments are effective sample media for mineral exploration programs in the North Mountain area.

Recommendations

Further detailed geochemical sampling of the C-horizon till (<63 µm) is warranted to establish the areal extent of the gold anomaly in till. Grid coverage is recommended, with suture lines across the inferred structure. A lower density, 10 kg till survey (heavy mineral concentrates, pebble counts and gold grain counts) is also recommended.

Additional stream sediment sampling (both <63 µm and HMC) is also warranted. Tighter sampling density is recommended along Kennedys Big Brook and associated tributaries.

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Musquodoboit Batholith Project and the Geology of NTS Map Area 11D/15 (Tangier)

L. J. Ham

Introduction

The Musquodoboit Batholith is the second largest granitoid pluton (~800 km^2) in the Meguma Terrane of mainland Nova Scotia (Fig. 1). The batholith intruded Cambro-Ordovician metasedimentary rocks of the Meguma Group ca. 370 Ma (Clarke and Halliday, 1980; Reynolds *et al.*, 1981). The body roughly parallels the coastline, extending east of Halifax to Sheet Harbour, and covers parts of three NTS map areas, 11D/13, 11D/14 and 11D/15.

Bedrock mapping of the batholith was initiated to compare its lithology and mineralogy with the larger (~7300 km^2) South Mountain Batholith of southern Nova Scotia (Fig. 1). Results of the mapping project were plotted digitally on 1:10 000 scale maps which were subsequently compiled (maps and databases) using AutoCad® and Fieldlog® to create 1:50 000 scale maps. Portions of the batholith that crop out on NTS 11D/13 have been illustrated in two open file maps that were released in 1998 (Minerals and Energy Branch Open File Maps 1998-5 and 1998-9). Maps of NTS areas 11D/14 and 11D/15 were released in 1999 (Ham, 1999a, 1999b) and results have been previously discussed for 11D/14 (Ham, 1999c). This report discusses the main features of NTS map area 11D/15 and illustrates those results in Figure 2.

Previous Work

The boundaries of the Musquodoboit Batholith were outlined by Fletcher and Faribault (1887); however, no attempt to re-map the batholith was undertaken until the

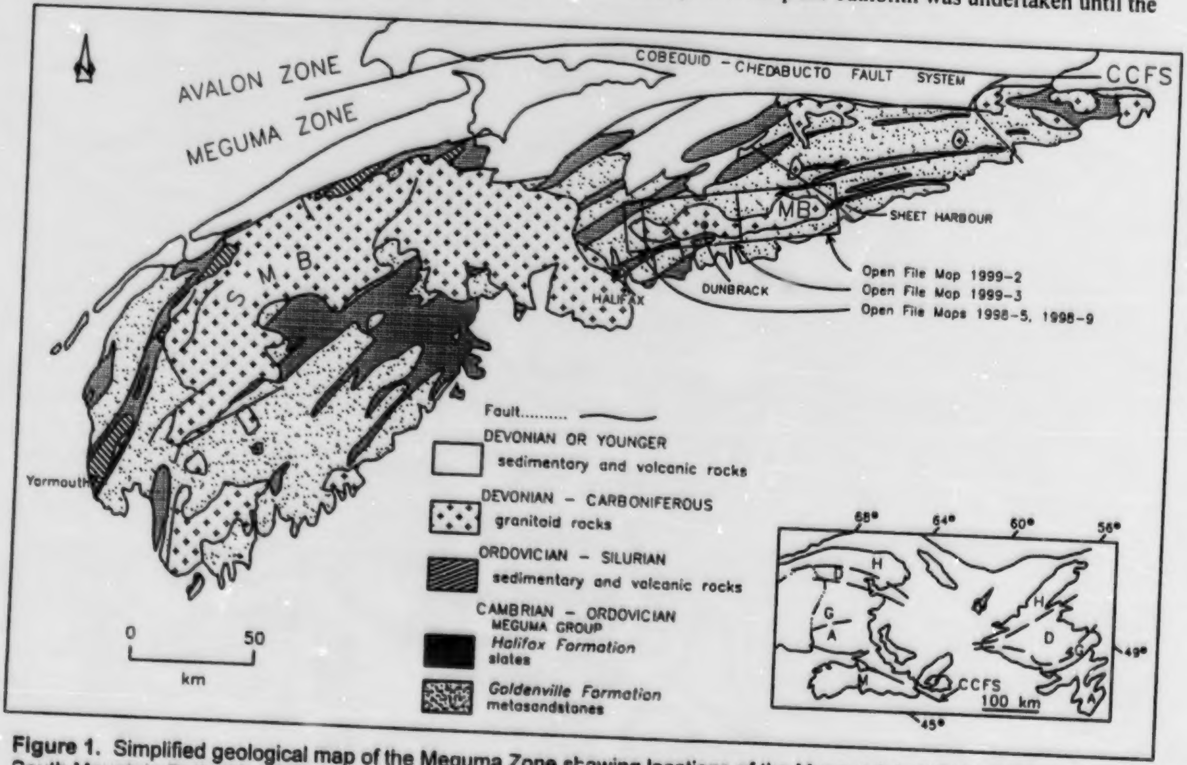
AVALON ZONE
MEGUMA ZONE
COBEQUID – CHEDABUCTO FAULT SYSTEM
CCFS
S. M. B.
MB
SHEET HARBOUR
HALIFAX
DUNBRACK
Open File Map 1999-2
Open File Map 1999-3
Open File Maps 1998-5, 1998-9
Yarmouth
Fault.........
DEVONIAN OR YOUNGER sedimentary and volcanic rocks
DEVONIAN – CARBONIFEROUS granitoid rocks
ORDOVICIAN – SILURIAN sedimentary and volcanic rocks
CAMBRIAN – ORDOVICIAN MEGUMA GROUP
Halifax Formation slates
Goldenville Formation metasandstones
0
50
km
68°
64°
60°
56°
49°
45°
H
D
G
A
M
CCFS
100 km

Figure 1. Simplified geological map of the Meguma Zone showing locations of the Musquodoboit Batholith (MB) and the South Mountain Batholith (SMB). The boundary between the Meguma and Avalon zones is marked by the Cobequid-Chedabucto Fault System (CCFS). Abbvreviations on the inset map are: Avalon Zone (A), Dunnage Zone (D), Gander Zone (G), Humber Zone (H) and Meguma Zone (MZ), representing zones of the Appalachians from Williams (1979).

1970s, when McKenzie and MacGillivary (1974) did work as part of a larger project comparing granites along the Eastern Shore. This work was followed by Jones and MacMichael (1976), who mapped a portion of the batholith. MacDonald (1981) studied the entire batholith as part of an M. Sc. thesis at Dalhousie University and subsequently reported on the results (MacDonald and Clarke, 1985).

Results of Mapping

The units are subdivided following the methodology and terminology used by the Nova Scotia Department of Natural Resources (NSDNR) for the South Mountain Batholith (e.g. MacDonald *et al.*, 1992). Based on field mapping, geochemistry and thin section petrography, the Musquodoboit Batholith can be subdivided lithologically into four distinct units. These units are described below in the assumed order of oldest to youngest, based on cross-cutting relationships, and illustrated in Figure 2.

Medium- to Coarse-grained Biotite Monzogranite

The apparently oldest rock type is a buff-white and pink, medium- to coarse-grained (locally K-feldspar megacrystic) biotite monzogranite. This unit contains biotite (6-12%), muscovite (trace - 1%) and cordierite (trace - 1%). Two narrow bodies of biotite monzogranite occur adjacent to the observed contact with metasedimentary rocks of the Meguma Group (Fig. 2), similar to the unit's distribution on NTS area 11D/14 (Ham, 1999c). A localized body of biotite monzogranite occurs in the Cowan Mill Pond area, at an embayment of the granite/metasedimentary rock contact. Another area of biotite monzogranite occurs on the eastern edge of Tangier Grand Lake, where contact-related phenomena occur, such as metasedimentary inclusions, xenoliths and biotite schlieren, as discussed in Ham (1997). All of these areas have associated polymetallic mineral occurrences (Fig. 2). Localized areas within the main body of the medium- to coarse-grained leucomonzogranite contain increased amounts of biotite. These rocks are classified as biotite monzogranite, but are exposed over limited areas and are not illustrated on the map.

Medium- to Coarse-grained Leucomonzogranite

The most abundant rock type in the map area is buff-white to pink, medium- to coarse-grained (locally K-feldspar megacrystic) biotite leucomonzogranite. It is mineralogically similar to the biotite monzogranite, but contains less biotite (4-8%, average 6%). This unit has only trace amounts of muscovite, thus differing from leucomonzogranite of the South Mountain Batholith which contains 3-10% muscovite. Cordierite is generally present (trace-2%) in all leucomonzogranitic rocks, and euhedral, blocky cordierite grains range in size from 0.3 cm - 1 cm in length. There are mappable areas underlying NTS 11D/14 that have increased modal percentages of cordierite (up to 4%; Ham, 1999c); however, no such concentrations are recognizable within NTS map area 11D/15.

'Specialized' Leucomonzogranite

Texturally and mineralogically variable leucomonzogranite occurs in several localities in the map area. Grain size ranges from fine- to medium-grained and textures vary from equigranular to porphyritic and pegmatitic. Airborne gamma-ray spectrometric surveys identified some of these rocks as having high equivalent uranium/equivalent thorium ratios (eU/eTh; Ford, 1991; Ham, 1993). These bodies were further defined by geological mapping and are shown in Figure 2.

'Specialized' leucomonzogranite bodies are generally located in the central portion of NTS area 11D/15 (Fig. 2) and have high muscovite contents (2-4%), low biotite contents (trace -2%), and are generally medium- to coarse-grained with textural variability (e.g. fine grained, aplite) noted on individual outcrops. Other textural varieties exist and range from fine grained to local areas of pronounced porphyritic texture (phenocrysts of K-feldspar, larger grains of biotite, rosettes of muscovite). The rocks are termed 'specialized' because of their high eU/eTh and high degree of textural and mineralogical variability.

Fine- to Medium-grained Leucomonzogranite

This unit in the eastern portion of NTS map area 11D/15 consists of a small body (~1 km^2) of buff-white to pink and red, fine- to medium-grained, equigranular leucomonzogranite occurring at the junction of Tangier Lake with Tangier River along the southern contact of the batholith (Fig. 2). This leucomonzogranite was not outlined by the airborne gamma-ray spectrometric survey (Ford, 1991) as a 'specialized' leucomonzogranite and generally does not contain elevated uranium/thorium ratios, or the extreme variability in texture or mineralogy. For these reasons it was not considered one of the 'specialized' bodies.

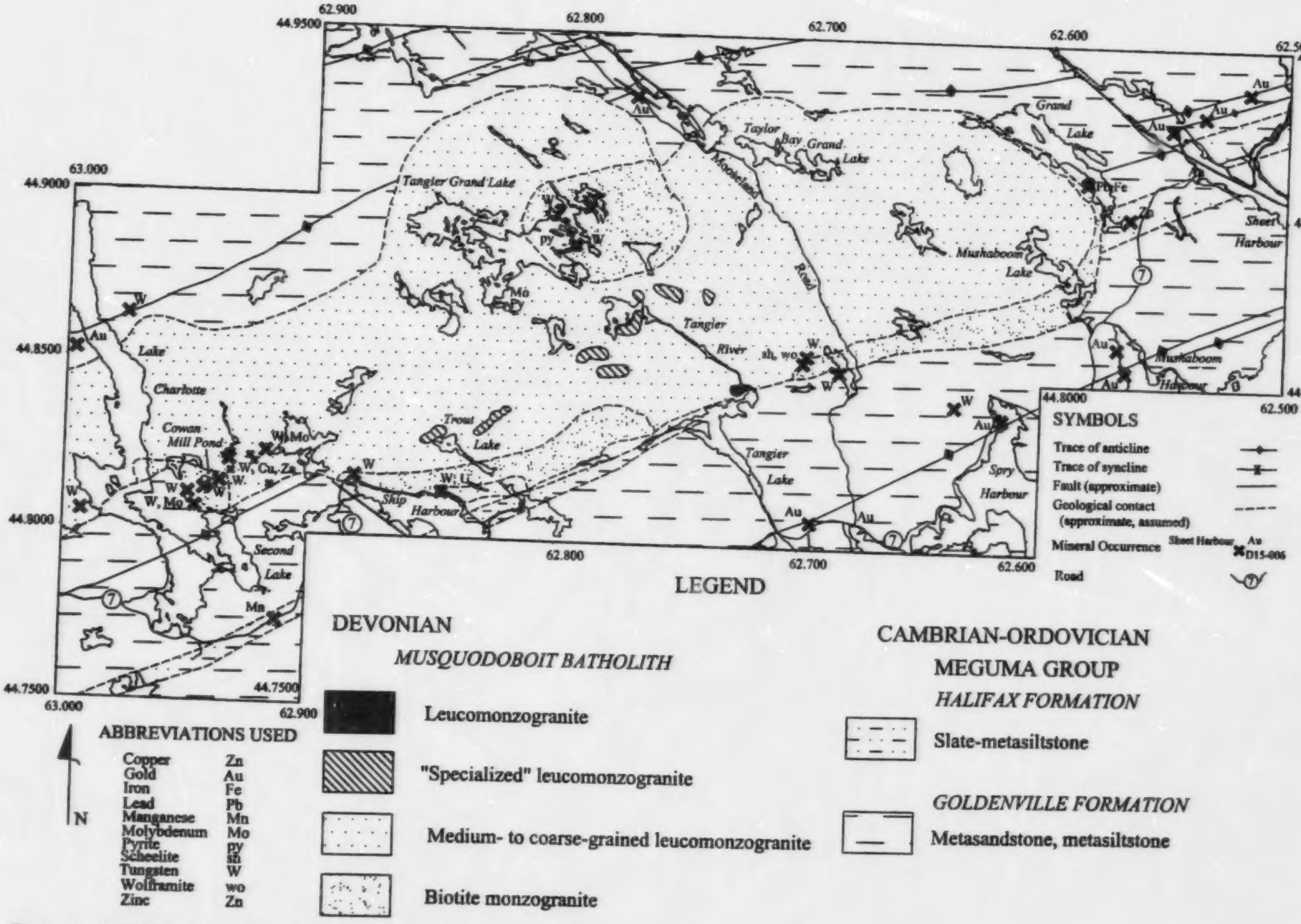

Figure 2. Simplified geology map and legend of NTS map area 11D/15.

Summary

The Musquodoboit Batholith can be classified using the same terminology as used for the South Mountain Batholith, although the medium- to coarse-grained leucomonzogranite of the Musquodoboit Batholith is muscovite-poor compared with similar rocks of the South Mountain Batholith. The rock types are:
(1) medium- to coarse-grained biotite monzogranite, which occurs adjacent to contacts with metasedimentary Meguma Group rocks; (2) medium- to coarse-grained biotite and biotite-cordierite leucomonzogranite, which comprises the main unit of the batholith;
(3) 'specialized' leucomonzogranite, which occurs in numerous, small bodies characterized by textural and mineralogical variability and other differences (decrease in grain size to fine grained, increase in muscovite content, porphyritic texture) from the coarser-grained leucomonzogranite; and (4) fine- to medium-grained leucomonzogranite which occurs in only one locality. The majority of the batholith underlying NTS map area 11D/15 consists of medium- to coarse-grained leucomonzogranite and contains cordierite (trace-2%), in addition to biotite (average 6%) and trace amounts of muscovite. 'Specialized' leucomonzogranite (or high ratio) bodies were outlined following the work of Ford (1991), who suggested that these rocks have an eU/eTh ratio greater than 1. These bodies were found to display variability in texture (porphyritic, pegmatitic, aplitic, equigranular) and mineralogy (abundances of muscovite, biotite).

Biotite-rich rocks (average 8% biotite) occur in three places along the southern Meguma Group metasedimentary/granite contact and one area underlying the eastern edge of Tangier Grand Lake. All of these bodies have associated polymetallic mineral occurrences and all occur near contacts with the metasedimentary rocks. In the Tangier Grand Lake area, although not geographically adjacent to a visible contact, other geological phenomena (metasedimentary xenoliths and inclusions, biotite schlieren) suggest that this area is close to the roof zone of the batholith. Association of mineral occurrences with the more biotite-rich rocks is curious and will be discussed further in the final report.

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Eastern Shore Compilation Project

L. J. Ham

Work began in earnest on the Eastern Shore gold compilation project this past summer (Fig. 1a). The first documented discovery of gold in the Eastern Shore area of Nova Scotia was made in 1858 at Mooseland (Heatherinton, 1868, in Bates, 1987). Geological maps were produced early in the 19th century by Faribault, and subsequent work was completed by Malcolm (1929). Since the first discoveries of gold, and particularly in the recent past, there has been considerable work undertaken by various mineral exploration companies, prospectors, universities and other parties, including both the Nova Scotia Department of Natural Resources (NSDNR) and the Geological Survey of Canada (GSC). There is a wealth of information dealing with various aspects of the gold districts on file with NSDNR, as well as in private research files and internal company reports.

The goals of the project are: (1) to compile existing information on the gold districts and surrounding areas of the Eastern Shore, (2) to incorporate all relevant information in a digital geological base map, (3) to produce databases and relevant cross-referencing links attached to the geological map, and (4) to write reports on selected gold districts. Information available in NSDNR assessment files, archived as hard copy and microfiche in the department library, has been indexed over the years in the NovaScan database. This information will also be incorporated by linking the NovaScan database to the Eastern Shore compilation.

Work on the project began in the easternmost portion of the Eastern Shore (NTS 11F/03, 04, 05 and 06; Fig. 1b) and included field visits to the gold districts and other known mineral occurrences. There have been no significant mineral occurrences discovered on NTS map area 11F/03. Field work included site visits to the former gold-producing districts (Fig. 1a) of Country Harbour, Upper and Lower Seal Harbour, Isaacs Harbour, Wine Harbour (11F/04), Forest Hill and Mile Lake (11F/05), and the W-Cu-Zn showing at Lazy Head (11F/06). Numerous smaller occurrences of various commodities were also visited on NTS map areas 11F/04, 05 and 06. Most of the former gold-producing sites were easily located and marked by abandoned mine shafts, old workings, adits or piles of waste rock and rubble. Table 1 lists the gold districts visited and the production history of each.

In addition, while this geological reconnaissance work was being undertaken, a trench for the Sable Island

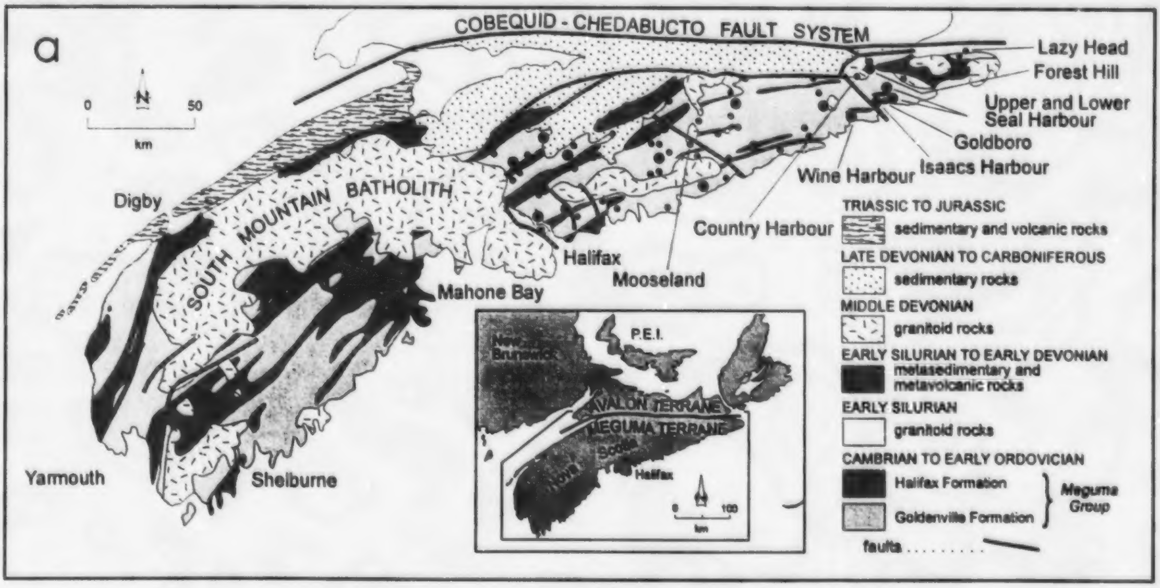

Figure 1a. Simplified geological map of the Meguma Terrane of Nova Scotia, modified after Keppie (2000), showing former gold districts and locations of the gold districts visited.

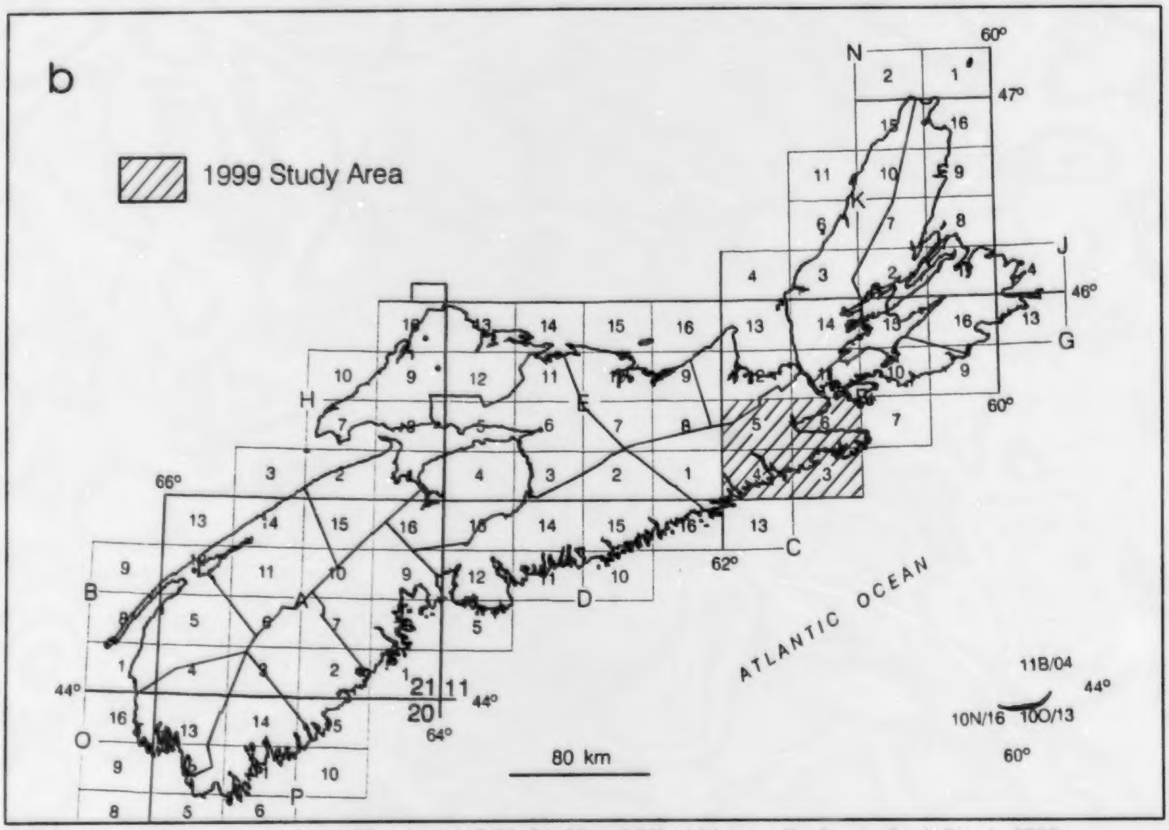

Figure 1b. Map showing the four NTS areas (11F/03, 04, 05 and 06) which were the focus of activities in 1999.

gas pipeline was also being excavated. The pipeline comes ashore in Goldboro (11F/04; Fig. 1a) and the excavation crossed many roads in the Eastern Shore area, allowing a 3 m deep, continuous window exposing surficial deposits and underlying bedrock along its length (Stea and MacDonald, 1999). In building the gas plant in Goldboro, bedrock was also exposed along the road leading to the plant (Upper Seal Harbour, Lower Seal Harbour and Isaacs Harbour gold districts; Fig. 1a), affording an excellent opportunity to examine the newly exposed rock.

Initial work from the mapping component of the project involved compiling base maps of the four NTS map areas (Fig. 2) using ArcView®. Extensive work over the summer involved using both the NSDNR Mineral Occurrence and Drillhole databases, and incorporating locations of all the mineral occurrences and drillholes on digital base maps. Locations of all mineral occurrences and drillholes were individually verified, and many subsequently re-located, by researching assessment files where the original locations are noted. The corrected locations of drillholes have been noted and are to be corrected at a later time in the

Legend

━	Pipeline route
─	Fault
✖	Mineral occurrence
●	Diamond-drill hole
⚒	Mine shafts

Geology

☐	M-LD - granite; tonalite, monzogranite, leucomonzogranite and leucogranite
▥	LS-EDA - Arisaig Group sediments undivided
▤	LD-ECH - Horton Group undivided
▧	ECW - Windsor Group undivided
▦	E-LCM - Mabou Group undivided
▒	DC - Fountain Lake Group volcanics and sediments, minor gabbro
■	COMh - Meguma Halifax Formation
☐	COMg - Meguma Goldenville Formation

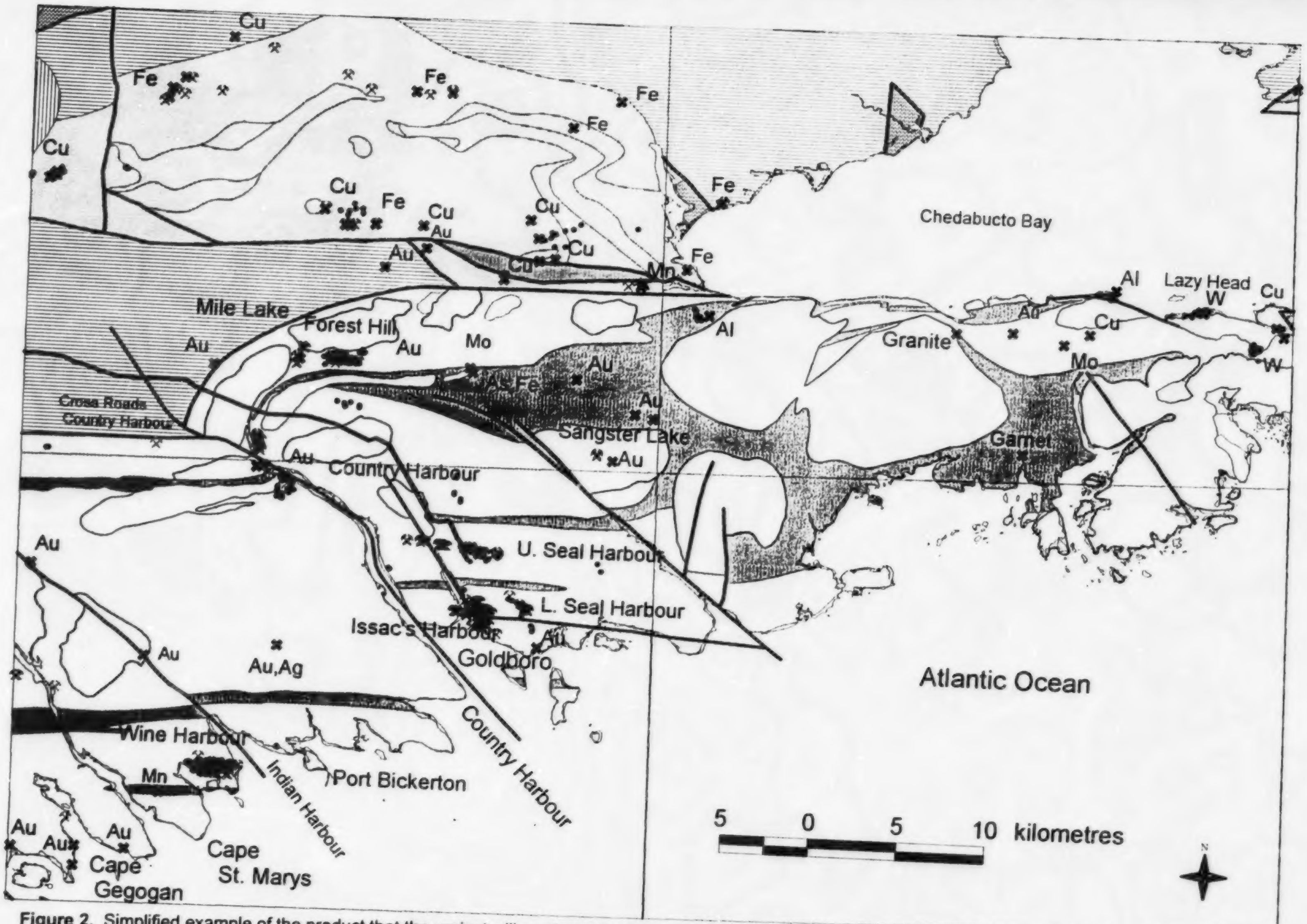

Figure 2. Simplified example of the product that the project will produce. This map combines the four NTS map sheets (11F/03, 04, 05 and 06) with simplified geology, mineral occurrences, diamond-drill holes, and abandoned mine shafts. Tables of data will be linked to the map, allowing users to click on an area and view relevant information, such as assessment reports, mines sections, geochemical data or photographs.

Table 1. Production histories of the gold districts visited in 1999.

Gold District	Years of Production	Gold Produced (Troy Ounces)
Country Harbour	1871-1951	9,959.7
Upper Seal Harbour	1893-1958	57,845.7
Lower Seal Harbour	1894-1949	34,188.2
Isaacs Harbour	1862-1958	39,694.3
Wine Harbour	1862-1939	42,346.5
Forest Hill	1895-1957	25,102.4

master drillhole database files. Using the newly compiled geological map of Nova Scotia (Keppie, 2000), the mineral occurrence and drillhole locations were plotted and the four NTS map sheets were displayed at a scale of 1:100 000 at the department's *Mining Matters for Nova Scotia* conference in November 1999. Geological information (outcrop locations, strike and dip information), particularly from Faribault's work, has been digitized from available reference maps after a reference search. However, this information has not yet been incorporated in the base maps because the necessary corrections have not been made to ensure that locations are accurate.

The next step of the project involves selecting and compiling information into the databases. The amount of information available in many areas is overwhelming, so care will be taken to select relevant and factual references.

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Mineral Resource Land-use Information and Policy

D. B. Hopper and F. J. Bonner

The Land-use Group consists of a senior planner and a land-use geologist who provide the Minerals and Energy Branch with information, policy and planning services that relate to mineral resources. The Land-use Group provides a link between the provincial government's interests in geoscience and the public's need for information on geology and mineral resources. Policy and regulatory analyses are conducted on land use, resource and environmental planning, and development initiatives that have the potential to affect mineral exploration and development. Principal clients include stakeholders interested in the use of land and resources, such as resource departments, municipal units, community economic development agencies, other non-government organizations and landowners. Activities in 1999 were undertaken in the following areas: (1) information services, (2) mapping and database development, (3) integrated resource management (IRM), (4) policy, assessments and review, (5) committees and administrative functions and (6) initiatives.

Information Services

The group provided clients with information on mineral resources, mineral use, mineral potential, land use, IRM and reclamation through maps, reports and digital products, using a geographic information system (GIS). The range of information services provided can be grouped into general inquiries, presentations and conferences, and promotional initiatives.

General Inquiries

A wide range of requests for information were received from the public, industry and government. Inquiries included issues such as acid drainage from abandoned pits and quarries, aquifer and flood-risk mapping, watershed mapping, land ownership status for prospectors, as well as geological information for community economic development, pipeline corridor planning, community water supply areas and industrial development.

Presentations and Conferences

In 1999, staff of the Land-use Group delivered two papers at conferences. One paper was presented in October to the GIS/GPS Conference held in Sydney, Nova Scotia, at the University College of Cape Breton entitled "Integrating Mineral Resources and Community Economic Development". The second paper, entitled "Mining, Land Use and Reclamation" was delivered as part of the technical program for the branch conference *Mining Matters for Nova Scotia '99* in November.

Four conferences were attended by members of the Land-use Group, including the annual Canadian Land Reclamation Association (CLRA) Conference, held in Saskatoon. CLRA is a national organization associated with the American Society for Surface Mining Reclamation. Several presentations focused on mining-related projects, including a program for managing abandoned aggregate properties and community involvement programs in mine-site reclamation. Land-use geologist F. J. Bonner became a member of the CLRA Executive in 1999.

An intergovernmental conference on Crown Land-use Planning and a forum on Private Land Stewardship were held in Ontario and attended by planner D. B. Hopper. These back-to-back events were hosted by the Ontario Ministry of Natural Resources and the Federal-Provincial Committee on Land Use. Presentations focused on the process used by the Province of Ontario to develop a land-use strategy for natural resource management on Crown lands. In addition, Ontario showcased their efforts in developing a network of private land stewardship initiatives. A 1999 report was prepared for the annual meeting of the Federal-Provincial Committee on Land Use profiling various land-use programs taking place in Nova Scotia.

Land-use staff attended sessions focused on environmental industries and community economic development using GIS and Internet technology, hosted by the Department of Finance. In addition, a poster presentation was made showing an example of a Mineral Resource Land Use (MRLU) map for the Atlantic Canada ESRI User's Conference, held in Dartmouth.

Promotional Initiatives

Articles were written for the Minerals and Energy Branch newsletter *Nova Scotia Minerals Update* on the subjects of land access, mineral resources and the protected areas agenda. Another article was prepared for *Planning Developments* to inform the municipal planning community about the department's IRM process.

Mapping and Database Development

The Land-use Group prepares maps and database projects on themes that integrate minerals, geology and land-use planning. The largest project is a set of digital theme maps covering the province, at a scale of 1:50 000, called the "Mineral Resource Land-use Atlas". This is a compilation of digital, mineral-based inventories and other geologic information stored as thematic layers. For example, these layers show locations and distributions of mineral occurrences, sand and gravel deposits, coal seam traces, operating and abandoned mines, quarries and pits, old gold workings, drillholes, geomorphological features, geohazard indicators, mining leases and permits, and special land-use designations. This summer several datasets were added to bring the project closer to completion. These included pit and quarry locations, sand and gravel deposits, points of geological interest, areas with sinkholes or karst topography, Crown limestone areas, protected wilderness areas, surface petroleum shows, eskers, gold mining areas, public beaches, and designated underground gas storage areas.

In other mapping projects, three maps are being brought to completion. The Land Designation and Ownership map, at a scale of 1:500 000, was completed at year-end and planned for release early in the new year as Open File Map ME 2000-1. This map shows a range of land designations that either protect or limit their use for resource development activity. Two other maps are being finalized, including a "Mineral Heritage of Nova Scotia" map and one showing the distribution of land access throughout the province.

Integrated Resource Management

The need to integrate geological and mineral resource interests with other land-use and resource planning is clearly identified in the province's Mineral Policy, Nova Scotia's Sustainable Development Strategy and the department's Integrated Resource Management (IRM) process. This year the land-use staff continued to contribute to the IRM process by providing planning and process advice, and digital mapping support to the regional teams.

The land-use geologist worked with regional geologists in representing geological and mineral-based interests, and the senior planner continued to provide planning and process advice to the regional IRM teams and IRM-Land-use Committee, including work on the IRM framework document.

Policy, Assessments and Reviews

The Land-use Group reviews and advises on land-use matters and policy initiatives as they affect mineral and energy resources and related environmental issues. This involves monitoring, reviewing and advising on land, environmental and natural resource policy, planning and development initiatives. The objective is to ensure the protection of mineral resources, land access and mineral tenure for mineral exploration in Nova Scotia. Local land-use priorities, land access, tenure and environmental issues are also monitored and considered in mineral resource management, exploration, mining and reclamation programs. The group also participates in various intra- and inter-departmental land-use, environmental planning, and strategic development initiatives. This service includes reviews and commentary on environmental assessment documents as well as development initiatives conducted by other departments. This year the Land-use Group began to develop a policy on the use of mapping information generated by DNR that shows the extent of underground coal workings below urban areas. Preparatory work was also provided toward a public review of the mineral policy action plan.

Aquaculture licenses and leases continued to be reviewed and input to a database. These license and lease applications are monitored to prevent undue conflict between the aquaculture industry and mineral resource interests.

Several requests came from the provincial Department of Transportation and Public Works for mineral resource and geological information needed in new highway development projects. A route location process gathers key data to screen out constraints such as geological hazards and prevent conflicts with mineral resources, including current and potential activity. Each request was provided with resource mapping information including (1) the Sydney to St. Peter's Corridor, Cape Breton Regional Municipality; (2) the proposed new Highway 113 bypass, which will link Highways 102 and 103; (3) a road re-alignment in the Digby-Weymouth area; and (4) proposed twinning of a section of Highway 101 between Ellershouse and Hortonville.

In addition, environmental assessment registration documents were reviewed, including the Thorburn Coal Development Project, the Maritimes and Northeast Pipeline (Halifax and Pt. Tupper laterals), and the Georgia Pacific Melford Gypsum Quarry project. Other reviews conducted involved the Department of Environment's Watershed Management Strategy and the Federal Government's initiative on Ocean Mining Regulations.

Committees and Administrative Functions

Participation on committees included work with the State of the Environment Report Committee (interdepartmental), the Restricted and Limited Land Use Database Committee (DNR), the Statement of Provincial Interest Mapping Committee (interdepartmental), the Miller Report Implementation Committee, the Information Technology Committee (DNR), and the Occupational Health and Safety Committee (DNR). The land-use geologist also coordinated the 1999 program for summer student employment.

1999 Initiatives

This year saw a greater focus on targeting community economic development agencies. Initial plans were discussed for organizing and presenting geological and mineral resource information to communities and local businesses. The Western Valley Development Agency was approached first as it is the only Regional Development Agency with mineral resource management identified in their strategic plan. An outcome of this meeting was the possibility of preparing mineral resource information kits for Regional Development Agencies. These could be used as part of a marketing package to provide information on the geology, mineral resources and geotourism features of Regional Development Agency jurisdictions.

The Land-use Group also met with representatives of the Town of Springhill to discuss the potential for developing a community-based project aimed at reclaiming the town's coal "duff" waste banks.

A new project was initiated in 1999 with the goal of compiling an inventory of the existing digital maps of abandoned surface mines (including pits and quarries) to determine their potential and priority for reclamation. Preliminary work included the development of a framework, goals and objectives and strategic actions. Work began on pilot studies with a client, Halifax C&D Recycling Ltd., to reclaim "acid-producing slate pits". Slate is a common road building material. Some slate units contain a significant amount of sulphide minerals (mainly pyrrhotite and pyrite). When sulphide minerals are exposed to oxygen and water an acidic solution is produced which may severely affect aquatic life downstream (e.g. fish kills). Two sites were initially selected in Halifax County: a slate pit on the Old Guysborough Road owned by Kimberley Clark and a pit located within Dollar Lake Provincial Park. The proposal for both of these projects is to use a manufactured soil cover derived from clean construction waste for reclaiming and re-contouring the land.

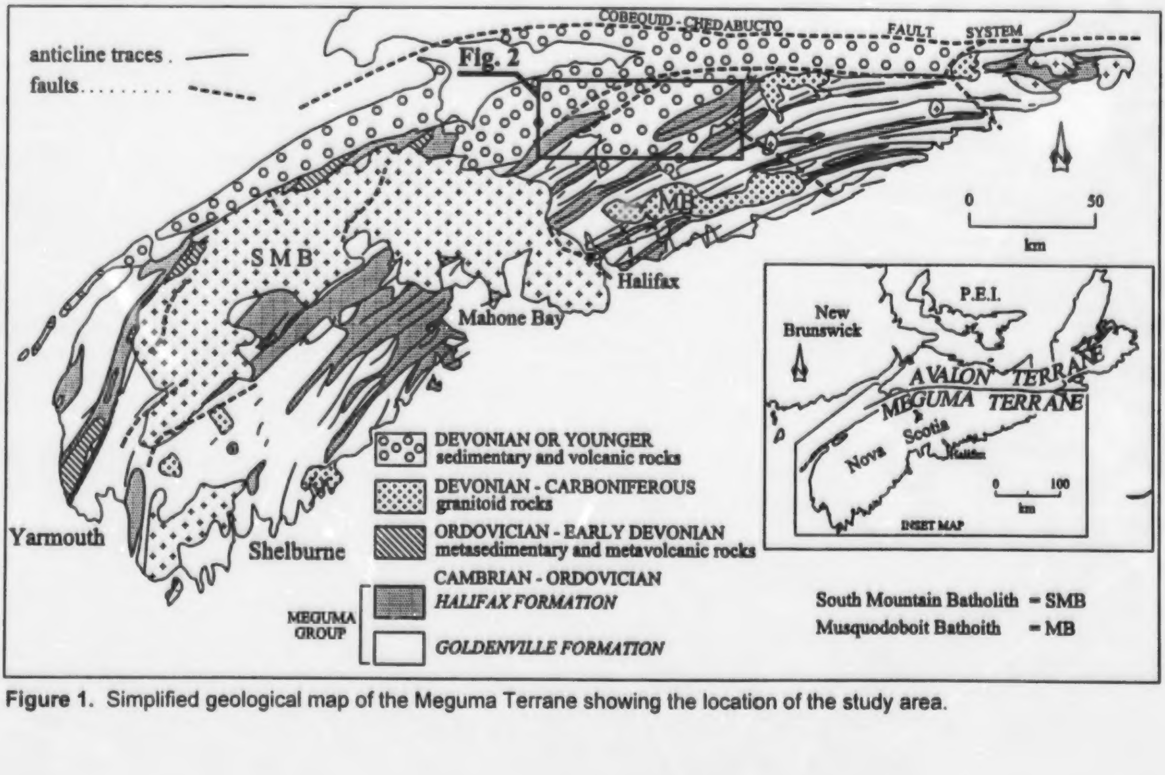
Geology of the Wittenburg Mountain Slate Belt, Centre Musquodoboit Area (NTS 11E/03), Nova Scotia

R. J. Horne, M. S. King and P. Young

Regional Geology

Wittenburg Mountain is located in the central Meguma Terrane of southern Nova Scotia (Fig. 1). The Meguma Terrane is dominated by metamorphosed sedimentary rocks of the Meguma Group and overlying Ordovician-Lower Devonian units, and Devonian to Carboniferous granitoids. The Meguma Group includes the lower, metasandstone-dominated Goldenville Formation and the overlying, slate-dominated Halifax Formation. The metamorphic rocks are folded into regional-scale northeast-trending folds, and at the current level of exposure the Goldenville Formation is exposed mainly in anticlinoria and the Halifax Formation and younger rocks in synclinoria, the latter defining slate belts. Granitoid plutons intrude the Meguma Group and truncate regional folds. Carboniferous sediments unconformably overlie the older rocks. Several regional-scale faults truncate all rock units in the area.

Digital elevation models and high resolution aeromagnetic data suggest geological similarities between the Wittenburg Mountain and Rawdon Hills slate belts in the central Meguma Terrane (Fig. 2). Recent mapping of the Rawdon Hills slate belt has provided detailed stratigraphic and structural data which can be related to the digital elevation and aeromagnetic data. In particular, the aeromagnetic data correspond to distinct lithologic units within the Halifax Formation, with high magnetic response corresponding to the lower Cunard Member and relatively low response to the upper Glen Brook Member (Horne and King, 1992; Fig. 2c). Digital elevation data indicate the Rawdon Hills slate belt defines a northeast-trending topographic high (Fig. 2b). Mapping has defined regional-scale faults on both margins of the slate belt, with a slate-belt-up sense of movement; thus, the slate belt defines a horst structure (Fig. 2b; Horne *et al.*, 1997).


anticline traces
faults
COBEQUID - CHEDABUCTO FAULT SYSTEM
Fig. 2
0
50
km
SMB
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Halifax
Mahone Bay
Yarmouth
Shelburne
P.E.I.
New Brunswick
AVALON TERRANE
MEGUMA TERRANE
Nova Scotia
Halifax
0
100
km
INSET MAP
DEVONIAN OR YOUNGER sedimentary and volcanic rocks
DEVONIAN - CARBONIFEROUS granitoid rocks
ORDOVICIAN - EARLY DEVONIAN metasedimentary and metavolcanic rocks
CAMBRIAN - ORDOVICIAN
MEGUMA GROUP
HALIFAX FORMATION
GOLDENVILLE FORMATION
South Mountain Batholith = SMB
Musquodoboit Bathoith = MB

Figure 1. Simplified geological map of the Meguma Terrane showing the location of the study area.

Similarities between the Rawdon Hills and Wittenburg Mountain slate belts are evident in the digital elevation models (DEM) and aeromagnetic data (Fig. 2). The aeromagnetic response suggests similar stratigraphy for both the Wittenburg Mountain slate belt and the Rawdon Hills slate belt, and the DEM data suggest the Wittenburg Mountain slate belt may also represent a horst structure. The following study presents the results from geological mapping of the Wittenburg Mountain slate belt in the Centre Musquodoboit area (Figs. 2, 3). The objective of the study was to evaluate the stratigraphy of the Halifax Formation and the possibility of faults at the margins of the slate belt, and thus evaluate the use of digital elevation models and aeromagnetic data as predictive tools for extending the details of recently mapped areas into areas where less detail has been established.

Wittenburg Mountain Slate Belt

Stratigraphy

The map area is underlain entirely by rocks of the Halifax Formation, which is undivided on previous maps (Faribault, 1899; Stevenson, 1959). The Halifax Formation has been subdivided during this study into the lower Cunard Member and overlying Glen Brook Member (Fig. 3). The Cunard Member consists of dark slate and lesser metasiltstone beds. Metasiltstone beds are typically cross-bedded and generally range from 2-30 cm in thickness; however, thicker beds occur locally. The Cunard Member is typically sulphide-rich with coarse pyrite and pyrrhotite occurring in slate and metasiltstone intervals. This unit corresponds to the areas of elevated aeromagnetic response along the margins of the Wittenburg Mountain slate belt (Fig. 2c).

The Glen Brook Member consists of green to grey, thinly bedded metasiltstone and slate. Colour variation between slate (generally grey) and metasiltstone (light grey-green) beds commonly results in a distinct colour banding. Metasiltstone beds are commonly cross-bedded, whereas slate beds are planar bedded. Locally, decimetre- to metre-thick metasandstone beds occur within this unit. The Glen Brook Member does not contain notable amounts of sulphide minerals and corresponds to the areas of relatively low aeromagnetic response in the centre of the Wittenburg Mountain slate belt (Fig. 2c).

Legend (Fig. 2)

Cretaceous

▦

Carboniferous

▽ *Mabou / Cumberland Groups*

☐ *Windsor Group*

⁘ *Horton Group*

Cambrian-Ordovician (Meguma Group)

▤ *Halifax Formation* — CO_{Hg} *Glen Brook member*
— CO_{Hc} *Cunard member*

▩ *Goldenville Formation*

Abbreviations

RHSB — Rawdon Hills Slate Belt
WMSB — Wittenburg Mountain Slate Belt

RF — Rawdon Fault
RCF — Roulston Corner Fault
MF — Meadowvale Fault
MVF — Musquodoboit Valley Fault
MB — Musquodoboit Basin

Structure

Regional Folds

The Wittenburg Mountain slate belt consists of a kilometre-scale synclinorium, herein referred to as the Wittenburg synclinorium. The overall synclinal form of the slate belt is supported by repetition of the lower Cunard Member on both margins (limbs; Fig. 3), as reflected in the aeromagnetic data (Fig. 2c). Three folds occur within the Glen Brook Member, including the South Branch Stewiacke Anticline (Faribault, 1899) and two unnamed synclines (Fig. 3). Bedding-cleavage relations and sedimentary structures indicate that all folds are upward facing. A well-developed continuous to spaced cleavage is axial planar to the regional folds. The typically steep dip of cleavage (Figs. 3, 4) indicates folds are steeply inclined. Fold hinges (bedding-cleavage intersection) in the map area plunge moderately to the northeast and southwest (Figs. 3, 4b).

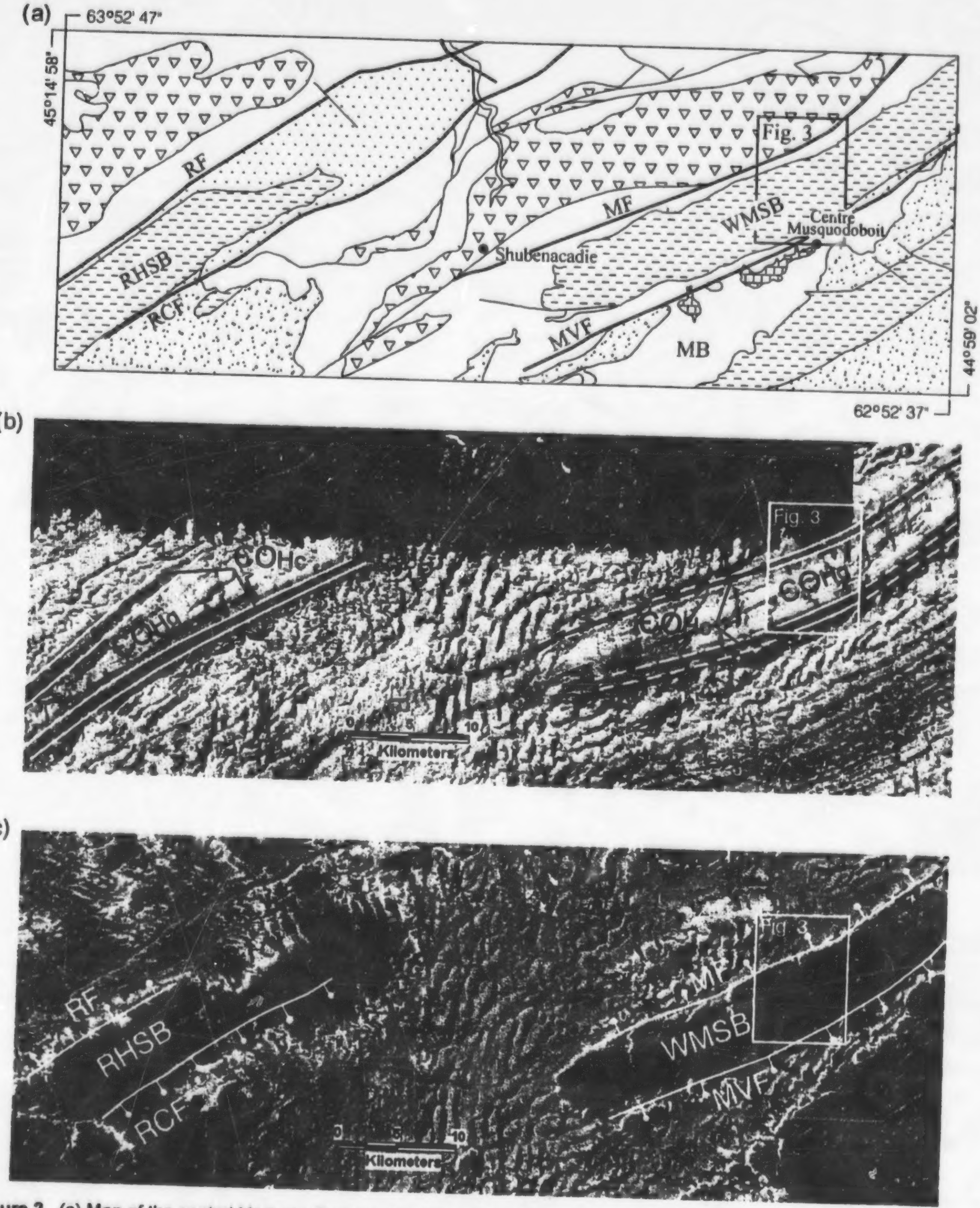


Figure 2. (a) Map of the central Meguma Terrane showing the geological setting of the study area. (b) Digital elevation data for the area shown in (a) showing the elevated, fault-bounded plateaus represented by the Rawdon Hills and Wittenburg Mountain slate belts. (c) Map of aeromagnetic data for the area shown in (a). Note how the geology of the Rawdon Hills (after Horne, 1993, 1995) and Wittenburg Mountain (for area of Fig. 3) slate belts correspond to aeromagnetic data.

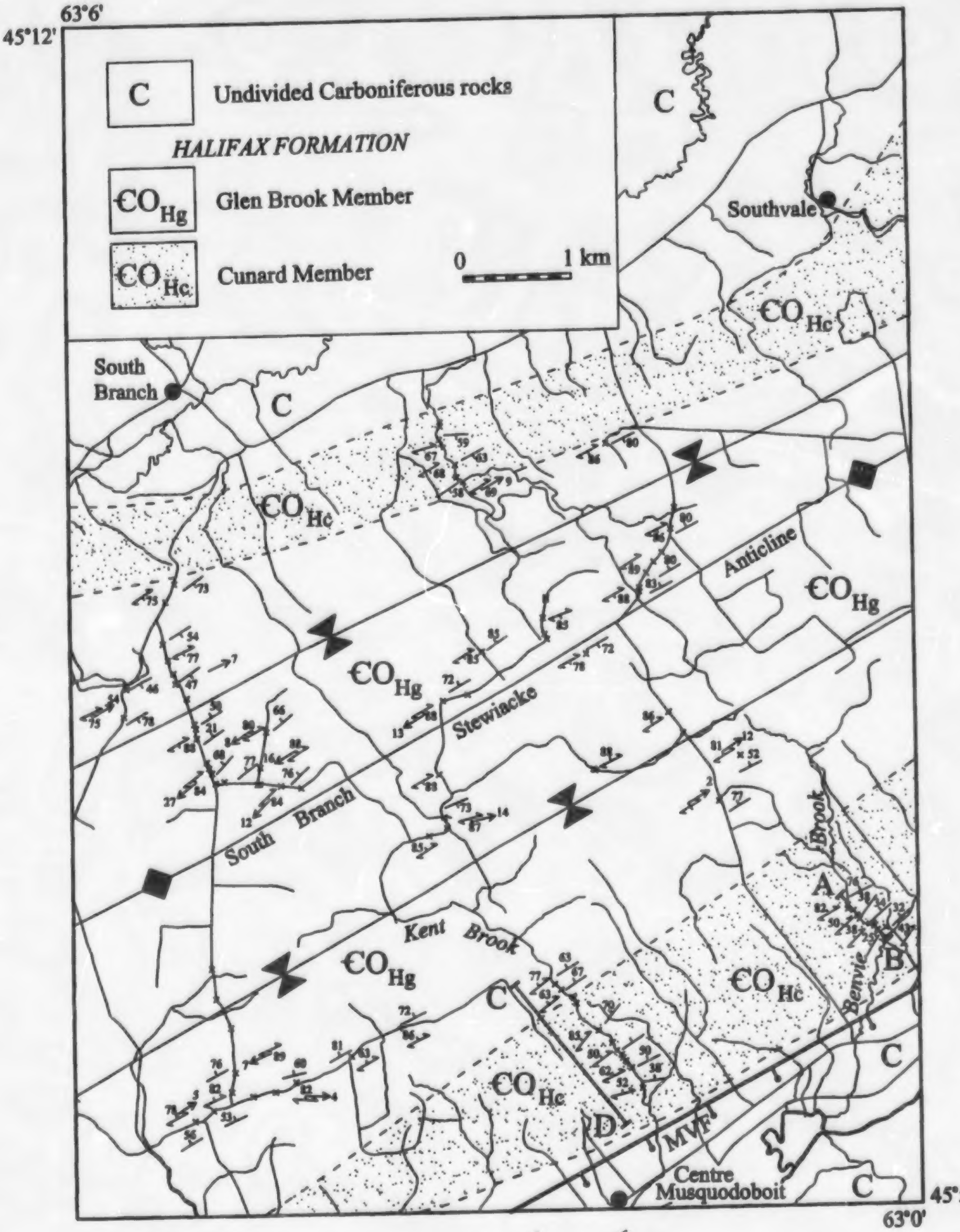


Figure 3. Geology of the map area, showing the location of sections lines A-B and C-D in Figure 5.

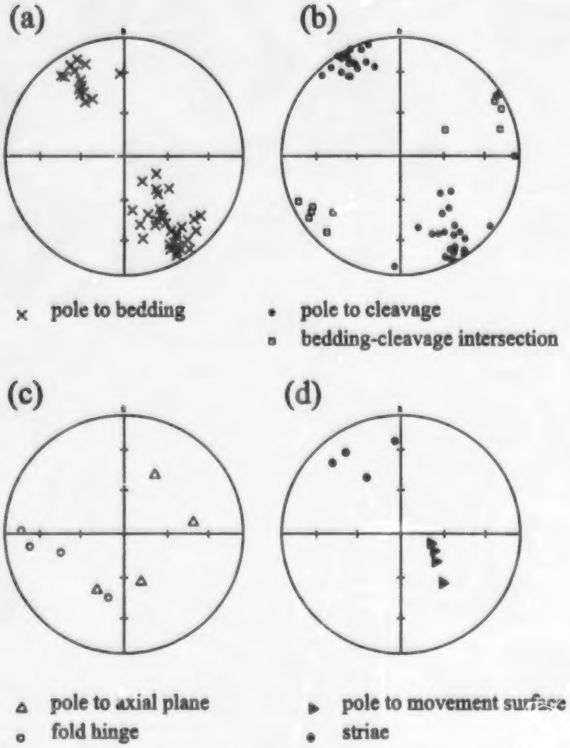


Figure 4. Stereoplots of (a) bedding and (b) cleavage and bedding-cleavage intersections for the map area and structural data for folds (c) and movement surfaces (d) for bedding-parallel faults in the fault-related folds of the Musquodoboit Valley Fault.

The fold geometry of the Wittenburg synclinorium is similar to the fold geometry in the Rawdon Hills synclinorium (Horne, 1993,1995). The lack of folds on the steep limbs of the synclinorium (Cunard Member) suggests that the South Branch Stewiacke Anticline and unnamed synclines within the Glen Brook Member formed after regional folding of the slate belt, and probably reflect shortening within the hinge of the synclinorium.

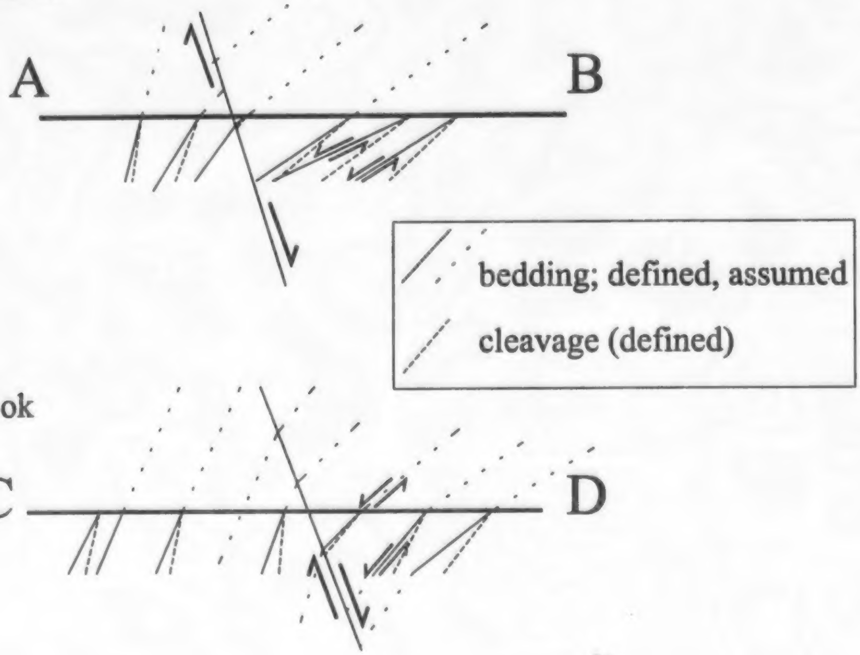
Musquodoboit Valley Fault

Boehner (1977) proposed that a steep fault defines the contact between Carboniferous rocks of the Musquodoboit Basin and the Wittenburg Mountain slate belt, which he referred to as the North Border Fault. As mentioned above, the Wittenburg Mountain slate belt defines an elevated block which, based on comparison with the Rawdon Hills slate belt, likely represents a fault-bounded horst. The presence of a fault between the Wittenburg Mountain slate belt and the Musquodoboit Basin is supported by diamond-drilling, which shows thick intervals of Middle Carboniferous Windsor Group sediments and a general lack of Lower Carboniferous Horton Group sediments adjacent to the slate belt (Hannon, 1974; Nash, 1975). Recent shallow seismic data indicate faulting of Cretaceous sediments in the area of the proposed fault (Fig. 2a), with a slate-belt-up sense of movement (Stea and Pullen, 1998). The name Musquodoboit Valley Fault (MVF) is used herein for a proposed fault along the southern margin of the Wittenburg Mountain slate belt (Figs. 2, 3).

Recent mapping has documented a wide zone of fault-related deformation affecting the Halifax Formation along the southern margin of the Wittenburg Mountain slate belt, supporting the presence of the Musquodoboit Valley Fault. The nature of this deformation is similar to that defined for the Rawdon Fault (Horne, 1993; Horne *et al.*, 1997) and defined by a regional-scale, fault-related fold, marginal to the fault. Within the fault zone, the southern limb of the Wittenburg synclinorium has been folded downward (i.e. southward), consistent with north-side-up, dip-slip movement on the Musquodoboit Valley Fault (Fig. 5). The bedding-cleavage angle is constant across the fold (Fig. 5a), supporting a post-regional folding, fault-related origin for folding. At the outcrop scale, deformation is mainly restricted to bedding-parallel faults. Mesoscale folds related to bedding-parallel faults are locally exposed and show an extensional sense of movement (Fig. 6; i.e., top to the northwest on northwest- dipping beds). Crenulation cleavage is developed within some bedding-parallel faults, also indicating an extensional sense of movement (Fig. 6d). Limited fold data (Fig. 4c) show a southwest plunge to fault-related folds, possibly indicating oblique displacement with a dextral component of slip. However, limited striae on bedding-parallel movement surfaces within the fault record mainly dip-slip movement (Fig. 4d).

Figure 4b shows a possible model for the Musquodoboit Valley Fault, with north-side-up displacement resulting in a fault-related, kink-style fold where bedding was rotated down toward the south. Cretaceous sediments (K) straddling the fault are deformed by similar fault-related folds; however, Pleistocene till (P) unconformably overlies the deformed Cretaceous sediments (Fig. 5b; Stea and Pullen, 1998). This kink-fold model accounts for the abrupt rotation of bedding within the fault zone and the sense of shear on bedding-parallel faults within the rotated limb of the fold.

(a) Benvie Brook



(b) Model

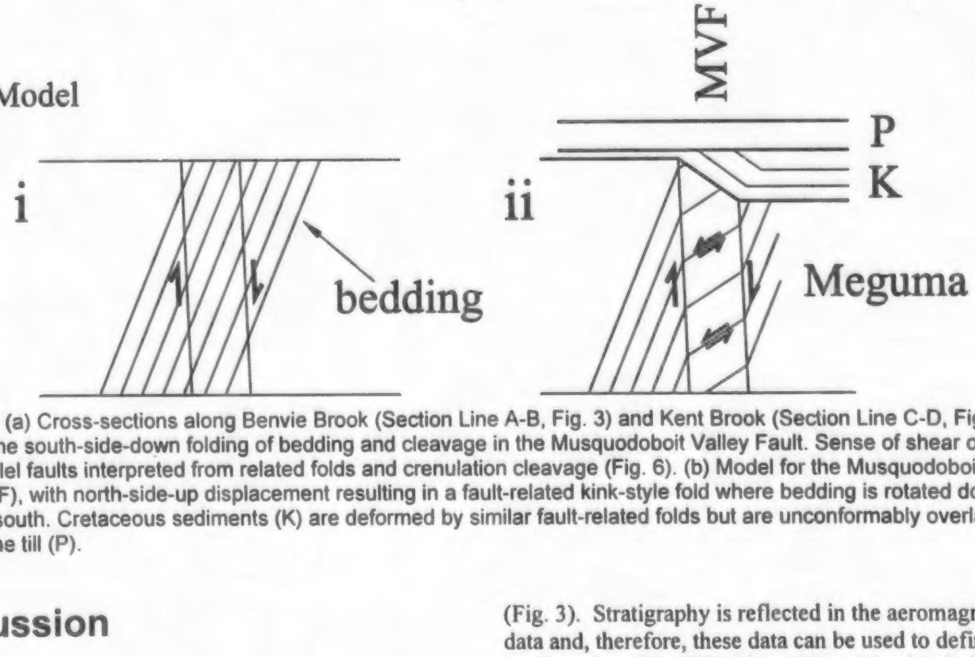


Figure 5. (a) Cross-sections along Benvie Brook (Section Line A-B, Fig. 3) and Kent Brook (Section Line C-D, Fig. 3) showing the south-side-down folding of bedding and cleavage in the Musquodoboit Valley Fault. Sense of shear on bedding-parallel faults interpreted from related folds and crenulation cleavage (Fig. 6). (b) Model for the Musquodoboit Valley Fault (MVF), with north-side-up displacement resulting in a fault-related kink-style fold where bedding is rotated down toward the south. Cretaceous sediments (K) are deformed by similar fault-related folds but are unconformably overlain by Pleistocene till (P).

Discussion

This study has confirmed similarities between the Wittenburg Mountain and Rawdon Hills slate belts. The stratigraphy of the Wittenburg Mountain slate belt is similar to that in the Rawdon Hills slate belt, consisting of lower Cunard and overlying Glen Brook members (Fig. 3). Stratigraphy is reflected in the aeromagnetic data and, therefore, these data can be used to define the stratigraphy of the Wittenburg Mountain slate belt outside the mapped area (i.e. assumed contacts, Fig. 2).

The Wittenburg Mountain slate belt forms an elevated, fault-bounded plateau. The Musquodoboit

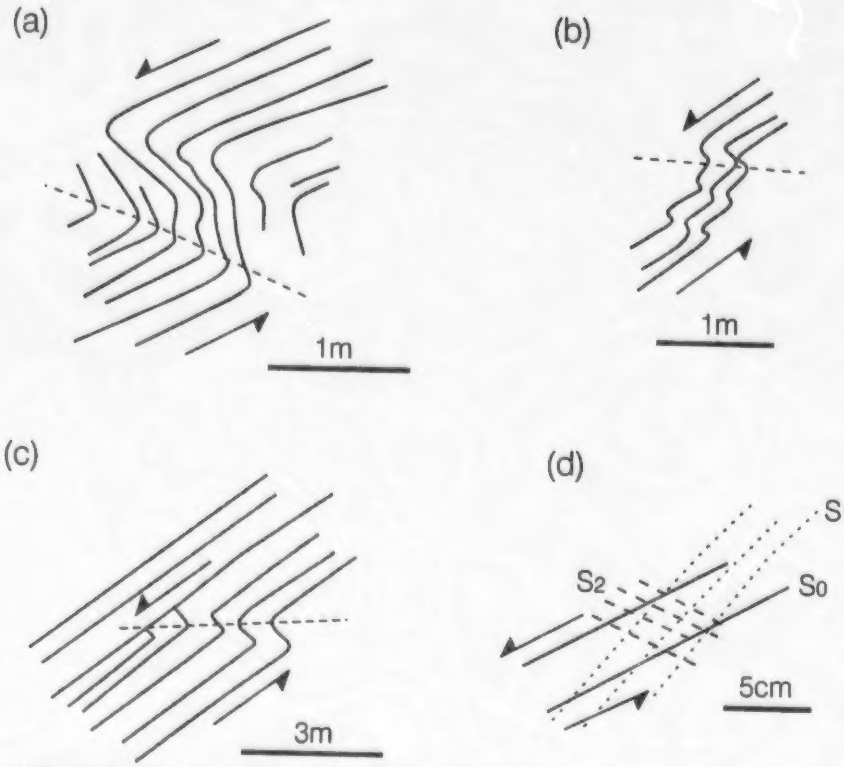


Figure 6. (a-c) Sketches of folds related to bedding-parallel faulting within the rotated limb of the Musquodoboit Valley Fault. All sketches are viewed toward the northeast and indicate an extensional sense of shear, consistent with limb rotation during faulting. (c) Sketch showing the relationship of a crenulation cleavage related to bedding-parallel faults indicating a sense of movement consistent with folds.

Valley Fault bounds the south margin and records slate-belt-up displacement (this study; Boehner, 1977). The north margin is bound by the Meadowvale Fault (Fig. 2) and also records slate-belt-up displacement (Giles and Boehner, 1982); thus, the slate belt is interpreted as a horst structure. Recent shallow seismic data indicate similar fault-related folds in the Cretaceous sediments located in the area adjacent to the Musquodoboit Valley Fault (Stea and Pullen, 1998), therefore constraining at least some post-Cretaceous displacement on the Musquodoboit Valley Fault. This is significant, as it suggests a young age for the formation of the Rawdon Hills and Wittenburg Mountain horst structures.

Bounding faults of the Wittenburg Mountain and Rawdon Hills horsts occur at or near the boundary of the Halifax and Goldenville formations and may reflect localization of strain between units of contrasting competency. However, the subsurface projection of the faults is unknown and the folding of bedding in the proposed model for the Musquodoboit Valley Fault (Fig. 5b) requires displacement to be oblique to bedding; if displacement was bedding-parallel then folding would not occur.

This study confirms the geological similarities of the Rawdon Hills and Wittenburg Mountain slate belts and thus demonstrates the application of aeromagnetic and digital elevation data for predicting the character of regional geological features when comparing areas with detailed information with less well known areas.

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Geology of the Weymouth - Church Point Area (NTS 21A/05 and 21B/08), Southwest Nova Scotia

R. J. Horne, C. E. White, C. Muir, M. D. Young and M. S. King

Introduction

Bedrock mapping in the Weymouth - Church Point area (Fig. 1a) was conducted during the 1999 field season. This mapping project is part of a regional program by the Nova Scotia Department of Natural Resources to produce 1:50 000 scale bedrock maps of the lower to middle Paleozoic rocks in the Digby-Yarmouth-Shelburne area (Fig. 1b). An overview of the mapping program, as well as the results of mapping in the Digby area (NTS map area 21A/12, Fig. 1a), is provided in White *et al.* (1999).

Outcrop exposure in the Weymouth - Church Point area is generally poor. Most of the area has a low topographic relief and is covered by glacial deposits (Stea *et al.*, 1992; Finck *et al.*, 1992). Areas of good exposure are limited to the Sissiboo River and a few coastal sections along St. Marys Bay (Fig. 2).

Cambrian-Devonian Metamorphic Rocks

Introduction

Metamorphic units include, from oldest to youngest, the Meguma Group, comprising the Goldenville and Halifax formations, the White Rock Formation and the Torbrook Formation (Fig. 2). This sequence is apparently conformable and has been folded into regional-scale, north-northeast-trending folds (Fig. 2). Field work in 1999 has resulted in significant changes to previous maps, most notably re-assignment of some units, subdivision of the Halifax Formation into three members, and recognition of a regional-scale shear zone overprinting regional folds. The interpretation presented here accounts, in the simplest way, for the distribution of the units identified, where the distribution of the Halifax, White Rock and Torbrook formations represents an extension of the Bear River Syncline defined northeast of the current study area (NTS map area 21A/12, Fig. 1; White *et al.*, 1999). The syncline plunges moderately to the northeast in the northeast part of the map area, with the distribution of stratigraphic units consistent with a change in structural level (Fig. 2). The area of White Rock Formation (Taylor, 1969) or White Rock - Kentville Formation rocks (MacDonald and Ham, 1994) exposed in the upper reaches of the Sissiboo River is interpreted here as Halifax Formation (Sissiboo member, see below), locally with thick (up to approximately 50 m) mafic sills.

Map Units

Goldenville Formation

The Goldenville Formation is the most extensive unit mapped, underlying the western part of the study area (Fig. 2). Exposure, is limited, however, and the following discussion largely reflects the cross-section exposed along Sissiboo River and in coastal exposures along St. Marys Bay.

The Goldenville Formation consists mainly of medium- to thick-bedded metasandstone, lesser green metasiltstone, and rare black slate, similar to the Goldenville Formation elsewhere in the Meguma Terrane (e.g. Schenk, 1995). Proportions of metasandstone and metasiltstone are highly variable. Typically this unit is characterized by regularly interbedded metasandstone and thin metasiltstone beds (Fig. 3a); however, sections of up to 50 m consisting mainly of metasiltstone, and extensive sections (hundreds of metres) where metasiltstone beds are rare and thin (~1-5 cm) occur. The lack of along-strike exposure and distinct marker horizons, combined with structural repetition by folding, makes determination of any stratigraphic significance in variation in the ratio of metasandstone vs. metasiltstone difficult.

Metasandstone beds are typically massive, although sedimentary structures occur locally, including planar laminations, cross bedding and cross-trough stratification. Grain size is often difficult to determine in the field, although the rock generally appears to consist of fine to medium sand. However, local lenses of coarse sand to fine-grained conglomerate (Fig. 3b) occur in coastal exposures south of Gilberts Cove, Cape Firmain and Little Brook (Fig. 2). These occurrences of relatively coarse sediment lie along a strike-parallel trend and likely represent the same stratigraphic level; conceivably they may define a useful

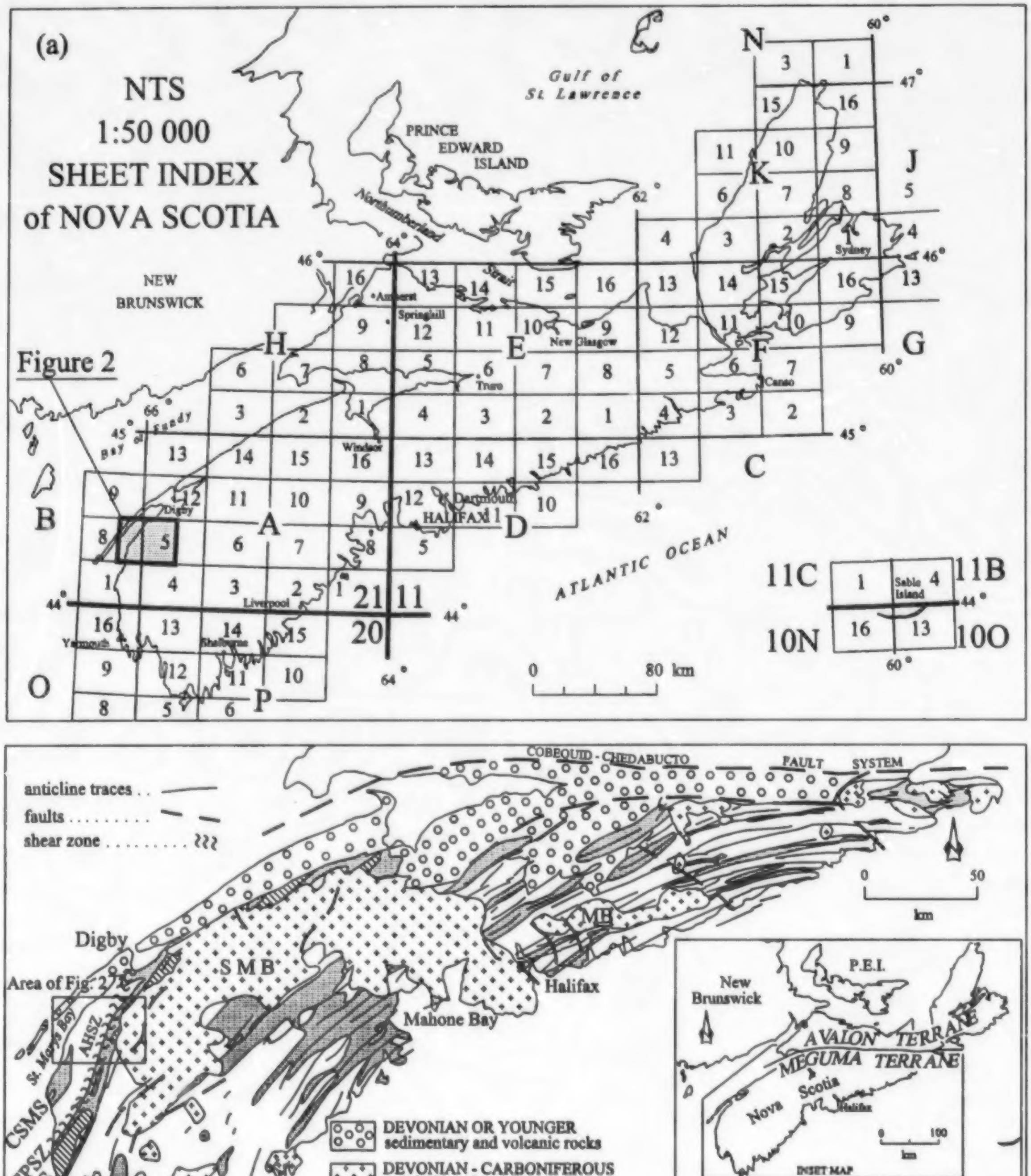


Figure 1. (a) NTS index map of Nova Scotia showing the boundary of the map area. (b) Simplified geology map of the Meguma Terrane showing the location of the map area.

marker horizon in an otherwise monotonous sequence. Metasiltstone beds are typically greenish and massive to very thinly bedded.

Concretions are abundant in metasandstone layers and occur throughout the entire section. There is no apparent variation in abundance of concretions within any part of the stratigraphy. It is possible that this reflects fold repetition of a thin stratigraphic section where concretions are abundant; however, up to 1 km of continuous strata are exposed on some fold limbs along the Sissiboo River. Concretions vary widely in shape, the most common occurring as bedding-parallel sheets with abrupt lateral terminations, and as cylinder-shaped or football-shaped concretions with their long axes within the bedding plane and parallel to the fold hinge (Figs. 3c, d). The composition and origin of the concretions are not known, although many are calcareous. Concretion boundaries cross-cut sedimentary structures and they are cleaved, suggesting a probable pre-tectonic, diagenetic origin.

Halifax Formation

The Halifax Formation in the map area has been subdivided into three lithologically distinct, conformable units, described below from oldest to youngest.

Bloomfield Member

The Bloomfield member is the lowermost unit of the Halifax Formation and is exposed along the western margin of the Bear River Syncline in the southern part of the map area. The Bloomfield member is also represented by clasts in till in the northern part of the map area (Fig. 2). This unit is not exposed, but inferred along the eastern margin of the Bear River Syncline in the southern portion of the map area (Fig. 2). The contact with the underlying Goldenville Formation is not exposed, but it is assumed to be gradational.

Till clasts in the north consist of distinct maroon and green, locally variegated, thinly bedded metasiltstone, similar to exposures of the Bloomfield member found along strike in the Digby area (White *et al.*, 1999). Exposures of this unit in the south part of the map area consist of green, very thinly to thinly bedded metasiltstone, similar to the green portion of this unit in the north part of the area.

Cunard Member

The Cunard member occurs along the entire length of the Bear River Syncline in the map area, although it varies in distribution depending on the structural level of exposure. The Cunard member is the dominant unit of the Bear River Syncline in the south, where the structural level is lower and the syncline is subhorizontal. However, this unit is restricted to the margins of the syncline at higher structural levels in the north, where the syncline plunges moderately to the northeast (Fig. 2). The Cunard member occurs above the Bloomfield member and a conformable relationship is assumed. The Cunard member consists of mainly dark (black), very thinly bedded slate and lesser thin- to medium-bedded metasandstone. Sulphide minerals (pyrite, pyrrhotite) are common to locally abundant.

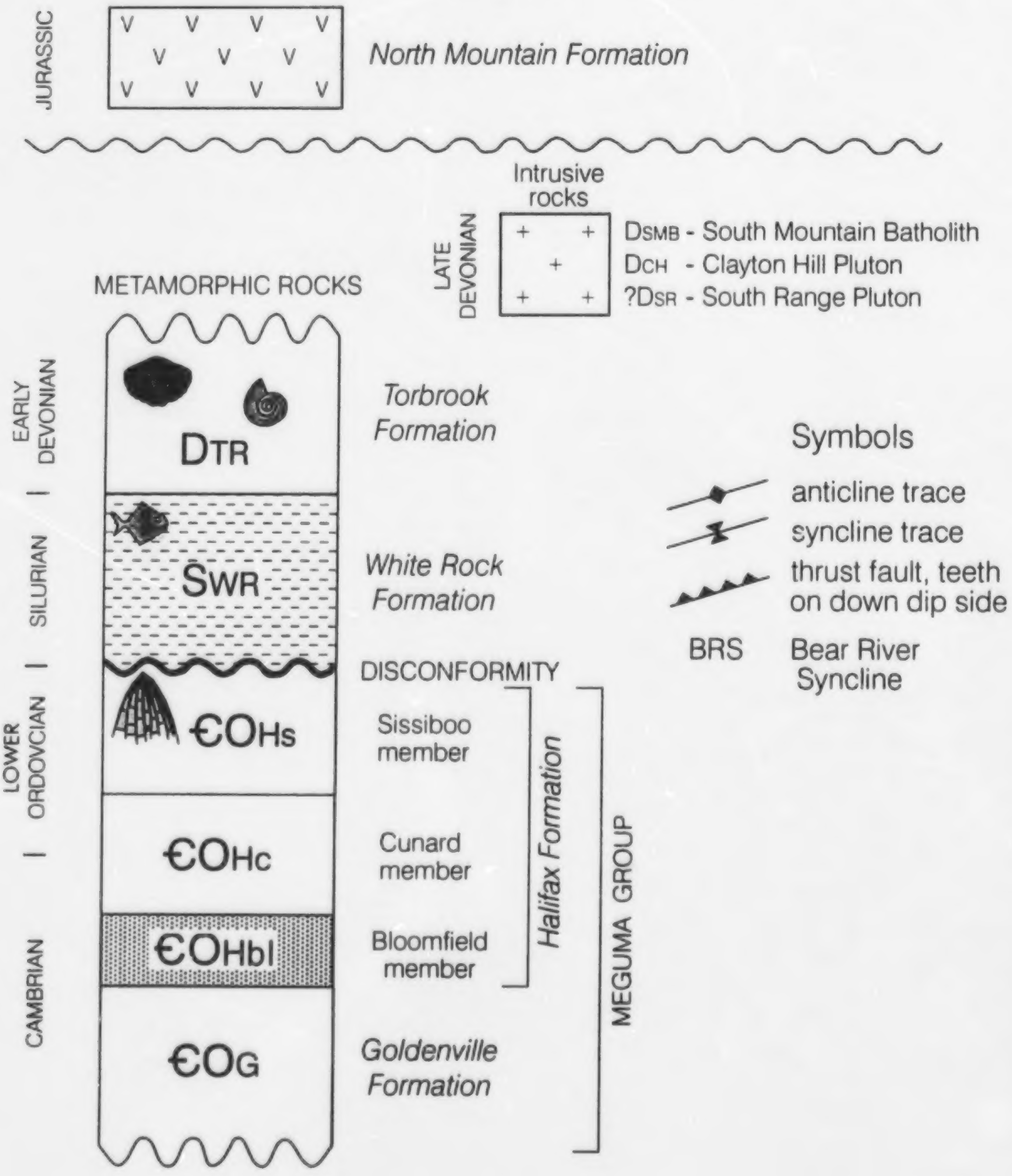
The Cunard member occupies the same stratigraphic position as the Acacia Brook member in the Digby area (White *et al.*, 1999), which mainly consists of very thinly bedded grey slate. We interpret the Cunard member to represent a lateral facies equivalent of the Acacia Brook member. This unit is typical of the Cunard member elsewhere in the Meguma Group (e.g. Waldron, 1992; Schenk, 1995).

Sissiboo Member

The Sissiboo member is exposed along the upper section of the Sissiboo River, and occupies the core of the Bear River Syncline at this structural level (Fig. 2). Our interpretation in this area is markedly different from that shown on previous maps, which show White Rock Formation rocks along the Sissiboo River in the area east of 'The Bend' (Fig. 2; Taylor, 1969; MacDonald and Ham, 1994). The current interpretation is based on the fact that structural continuity across the syncline demands stratigraphic repetition (in Taylor's interpretation White Rock Formation is shown on the east limb and Halifax Formation on the west limb of the syncline) and a lack of variation in lithology. Exposure east of 'The Bend', previously assigned as White Rock Formation, is limited to only a few outcrops of mafic sills (noted by Taylor, 1969) and metasiltstone within the contact aureole of the South Mountain Batholith (see below). This makes differentiation of these rocks as belonging to the White Rock Formation based on lithology difficult. Taylor also reported mafic volcanic rocks in this area; however, our mapping shows these rocks are actually mafic sills.

The Sissiboo member consists of planar stratified, interbedded, very thin to thin bedded grey slate and pale grey metasiltstone beds, resulting in a distinct colour banding (Fig. 4a). Metasiltstone beds generally are characterized by cross-bedded sedimentary structures (Fig. 4a), whereas slate is planar laminated. Although the Sissiboo member is distinct from the Bear River member described in the Digby area (White *et al.*, 1999), the two units are lithologically and sedimentologically similar (e.g. interbedded slate - metasiltstone; thin cross-bedded metasiltstone) and

LEGEND


JURASSIC
North Mountain Formation
Intrusive rocks
LATE DEVONIAN
DSMB - South Mountain Batholith
DCH - Clayton Hill Pluton
?DSR - South Range Pluton
METAMORPHIC ROCKS
EARLY DEVONIAN
DTR
Torbrook Formation
SILURIAN
SWR
White Rock Formation
DISCONFORMITY
LOWER ORDOVCIAN
ЄOHs
Sissiboo member
ЄOHc
Cunard member
ЄOHbl
Bloomfield member
Halifax Formation
CAMBRIAN
ЄOG
Goldenville Formation
MEGUMA GROUP
Symbols
anticline trace
syncline trace
thrust fault, teeth on down dip side
BRS
Bear River Syncline

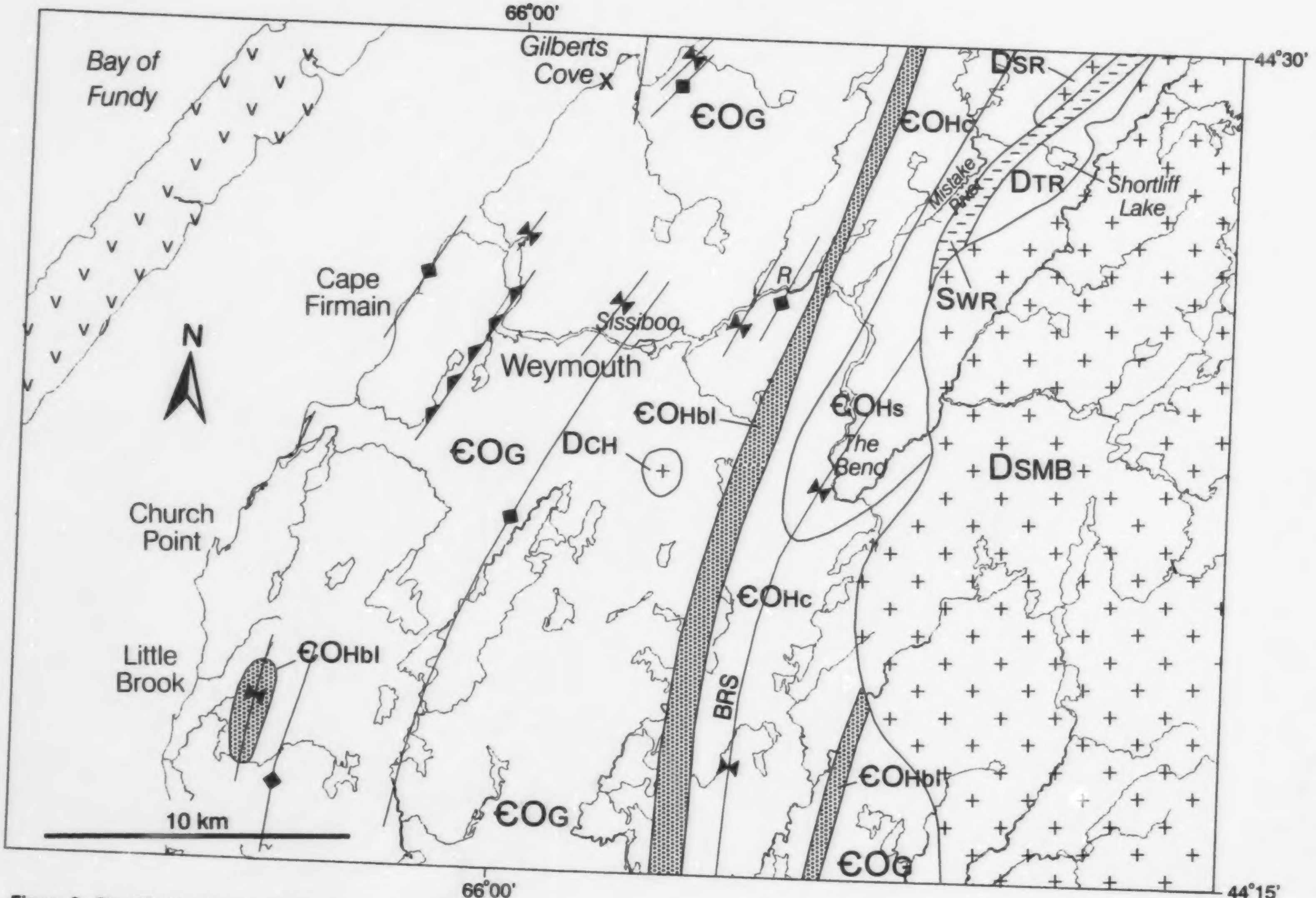


Figure 2. Simplified geology map of the Weymouth - Church Point area.

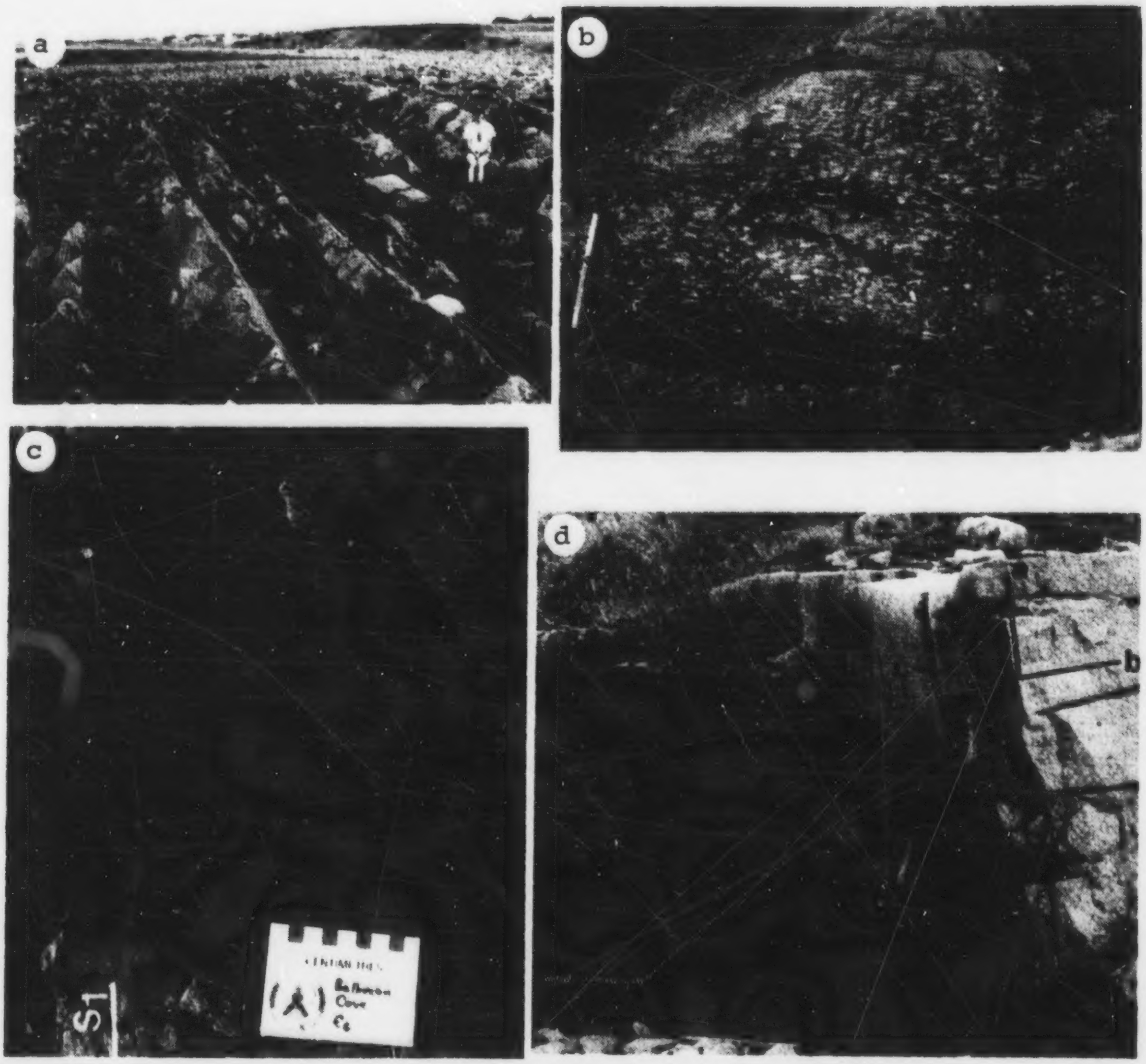


Figure 3. (a) Photograph of an outcrop of typical Goldenville Formation rocks, consisting of medium- to very thick-bedded metasandstone and interbedded thin- to medium-bedded metasiltstone. (b) Photograph of mud chip metaconglomerate in the Goldenville Formation. Mud chips are stretched parallel to the fold hinge (arrow, l_1). (c) Photograph of concretion in fold profile view showing the apparent flattening parallel to fold-related cleavage (S_1). (d) Photograph of Goldenville Formation outcrop showing several concretions. Fold axis indicated, with a-c defining the fold profile and a-b the axial plane (here parallel to cleavage, S_1); bottle of suntan lotion for scale.

occur at the same stratigraphic position. Thus, we interpret them to represent facies variations of the same stratigraphic unit.

White Rock Formation

The White Rock Formation is exposed along Mill Brook (which flows west from Shortliff Lake, Fig. 2) where it is represented by thick (several metres), massive quartzite beds, characteristic of this unit, and interbedded metasiltstone and marly metasiltstone. Recognition of the White Rock Formation in this area is consistent with along-strike extension of this unit from the Bear River area to the northeast (White *et al.*, 1999). The relationship with the Sissiboo member is unknown, although a disconformity between the Halifax and White Rock formations was proposed in the Bear River area (White *et al.*, 1999; Horne *et al.*, 2000).

Torbrook Formation

The Torbrook Formation occurs in the northeast part of the map area, underlying the area south of the White Rock Formation. A single outcrop of Torbrook Formation rocks occurs on the south side of Shortliff Lake (Fig. 2) and this unit was intersected in diamond-drill holes on the north and south sides of Shortliff Lake (Dakers, 1982). Abundant angular boulders of this unit occur along the road southwest of Shortliff Lake. In the map area, the Torbrook Formation consists of metasiltstone, locally characterized by beds with abundant well preserved macrofossils, including brachiopods, pelecypods, gastropods, crinoids and other shell fragments (Fig. 4b). Fossils are typically well preserved, displaying only minor strain. As with the White Rock Formation, the distribution of the Torbrook Formation is consistent with along-strike continuity of this unit from the Bear River area (White *et al.*, 1999).

Intrusive Rocks

South Mountain Batholith

The South Mountain Batholith in the study area has been mapped by MacDonald and Ham (1994) and was not systematically addressed during this study. However, some mapping was conducted along new logging roads and generally supported the distribution of units (biotite monzogranite and granodiorite) shown by MacDonald and Ham (1994).

Clayton Hill Pluton (Leucomonzogranite)

The Clayton Hill pluton consists of a small intrusion south of Weymouth Falls (Fig. 2). There is no exposure of the pluton; however, its distribution is reasonably well constrained by till clasts (Fig. 5a, Table 1; Finck *et al.*, 1994). Exposure of granite till is particularly well presented along a new woods road on the west side of Highway 340, which cuts across the proposed limits of the pluton, and in gravel pits on the north side of the road to Danvers, just east of Highway 340 (Fig. 5a). The pluton was also outlined on the basis of boulder distribution by Dakers (1982). The Clayton Hill pluton, as defined by till clasts and boulders in this study, occurs in an area of low response in the aeromagnetic data (Fig. 5b).

The Clayton Hill pluton consists of massive, medium-grained, equigranular leucomonzogranite. The term leucomonzogranite is adopted from MacDonald *et al.* (1992) and indicates a granite-syenogranite composition with 4-6% mafic minerals. The Clayton Hill pluton is comparable to medium-grained leucomonzogranite units in the South Mountain Batholith. Small (typically 2-10 mm) miarolitic cavities occur throughout the intrusion, locally accounting for a few percent by volume. Oxidation stains around the miarolitic cavities resulted from weathering of sulphide minerals (pyrite, chalcopyrite) within the cavities. Pegmatite dykes and quartz veins are common in the leucomonzogranite boulders throughout the area, the latter often containing coarse sulphides (see below for details). The abundant miarolitic cavities, pegmatite and quartz veins in this intrusion indicate it was relatively fluid-rich at the time of crystallization. Certainly the abundance of miarolitic cavities, veins and pegmatite dykes is high in comparison to most fine- to medium-grained leucomonzogranite units in the South Mountain Batholith (R. J. Horne, personal observation). The age of the Clayton Hill pluton is unknown; however, the pluton is similar to rocks of the South Mountain Batholith and it may have a similar Devonian-Carboniferous age.

South Range Pluton (Diorite)

Outcrop of a medium-grained mafic intrusive rock occurs just north of Shortliff Lake. The composition of this unit has not been determined, although Dakers (1982) reported the occurrence of olivine diabase and amygdaloidal basalt in this area. Dakers (1982) suggested the diabase reflects a sill and interpreted the basalt to represent the White Rock Formation. MacDonald and Ham (1994) show a mafic intrusion in the area, indicating the presence of gabbro, quartz gabbro and peridotite boulders.

The relationship between the mafic intrusive rocks and the Torbrook and White Rock formations is unknown. However, the outcrop of mafic intrusive rock observed is characterized by abundant slickensided fractures, commonly coated with epidote, suggesting a possible fault contact. This could explain the apparent strike-parallel contact of this intrusive unit.

Mafic Sills

A few mafic sills occur within the map area, but they are notably less common than in the Bear River area where they are abundant (White *et al.*, 1999). Thick, medium to coarse sills are exposed in the Sissiboo member along the Sissiboo River east of 'The Bend'. These sills are locally foliated and highly fractured, possibly reflecting a north-northeast-trending fault along this segment of the river, as proposed by MacDonald and Ham (1994).

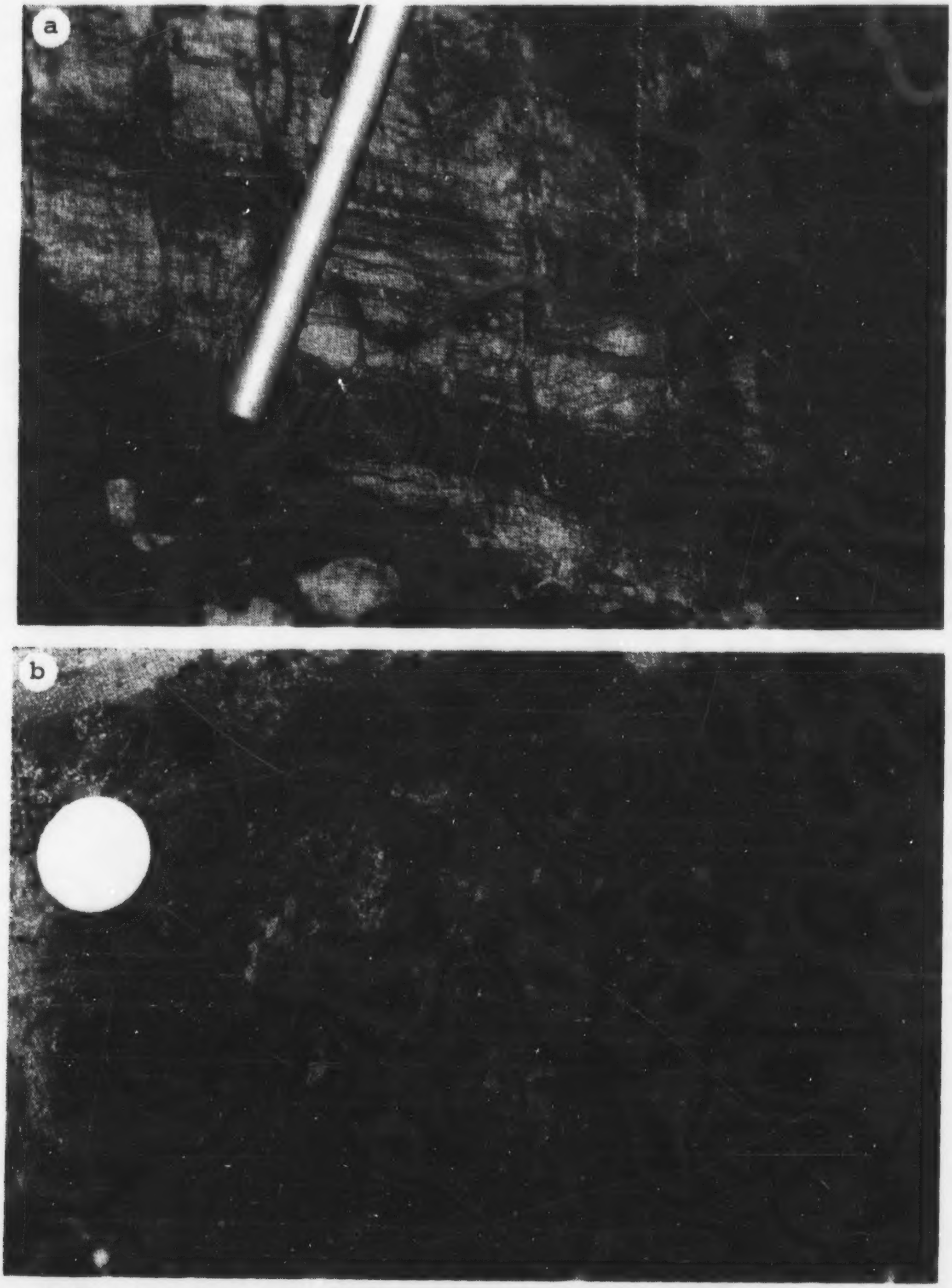


Figure 4. (a) Photograph of outcrop of the Sissiboo member, Halifax Formation, showing typical colour-banding defined by interbedded dark slate and pale coloured metasiltstone layers, the latter with features which may reflect wavy and ripple-bedded forms and bioturbation (R. Naylor, personal communication, 1999). (b) Photograph of bedding surface on fossiliferous rock of the Torbrook Formation (quarter for scale).

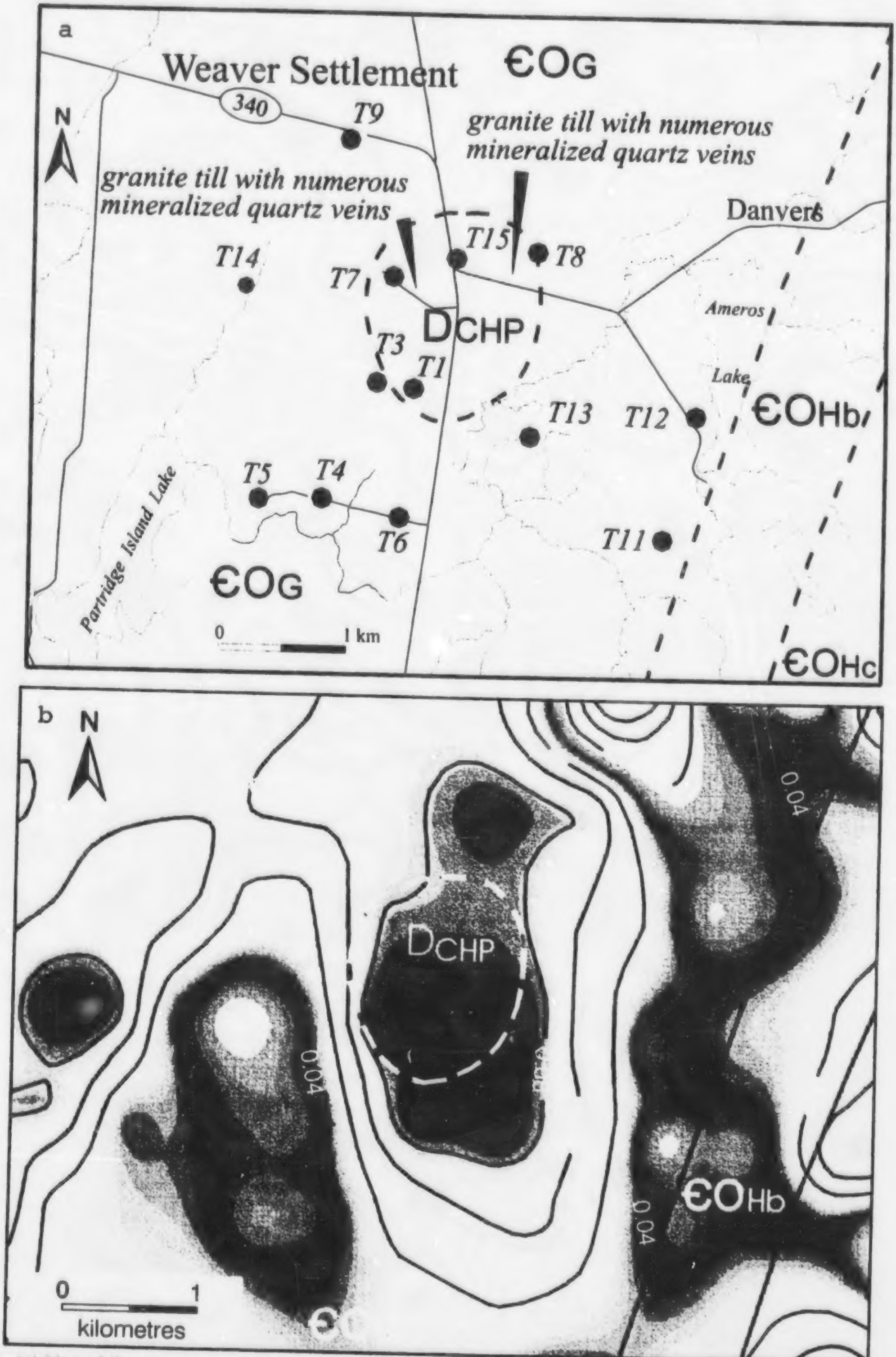


Figure 5. (a) Map of the area around the Clayton Hill pluton showing the location of till samples providing clast lithology (Table 1) used to define the extent of the Clayton Hill pluton, and showing the location of mineralized quartz veins cutting granite boulders. (b) Aeromagnetic data for the area around the Clayton Hill pluton showing the low magnetic response (dark shade) corresponding to the pluton. Magnetic data are shown as shading and annotated by contour lines. Contour data given in nT/m. See Figure 2 for geological legend.

Table 1. Results of pebble clast counts for till samples around the Clayton Hill Pluton. Values given as a percentage of total clast content. See Figure 5a for location of samples.

	% Meguma	% Granite	% Foreign	Comments
T1	55	45		Meguma includes abundant hornfels. Angular granite.
T2				No data available.
T3	92	3.5	4.5	Almost completely spotted hornfels.
T4	89	4	7	Mainly subangular Goldenville.
T5	87	4.5	8.5	Mainly hornfels and some skarn.
T6	75	11	14	Abundant spotted hornfels. Granite is angular.
T7	6	94		Granite is angular. Nine quartz vein clasts.
T8	66	18	16	Meguma mainly spotted hornfels. Angular granite.
T9	29	2	69	Well rounded foreign. Rounded Meguma. Microgranite.
T10				No data available.
T11	84	5	11	Mostly spotted hornfels.
T12	76		24	Meguma mainly slate, subrounded. Foreign small, rounded.
T13	7		93	Well round foreign clasts. Meguma is spotted hornfels.
T14	100			Angular Meguma, not spotted hornfels.
T15	63	33	4	Granite highly altered, hematized, chloritized. Meguma spotted hornfels. Several quartz vein clasts.

A few mafic sills occur in the Cunard member exposed on the Sissiboo River near Sissiboo Falls and in the Goldenville Formation exposed in the Firmain Point area (Fig. 2). These sills are similar to Type II sills defined in the Bear River area (e.g. White *et al.*, 1999).

Structure - Metamorphism

Regional Folds

The dominant structures of the area are regional, kilometre-scale folds (Figs. 2, 6a) developed during the Acadian Orogeny. Folds are apparent from the distribution of units in the Bear River Syncline and have been defined by bedding and cleavage data (Fig. 6b, c) in the Goldenville Formation. However, poor exposure in the Goldenville Formation inhibits confident extension of the trace of fold hinges in this unit. Axial planar cleavage trends north-northeast (Fig. 6b) and is represented by a fine, continuous cleavage in metasiltstone and slate, and a spaced cleavage in metasandstone. Cleavage refraction occurs between slate intervals, where cleavage is steep and axial planar, and metasandstone beds, where cleavage defines a convergent fan about the axial plane. Folds plunge moderately to the northeast in the northern part of the area, but are shallow plunging to subhorizontal in the south (Fig. 6a, b).

Significant hinge-parallel extension is locally recorded by stretched quartz and feldspar grains and mud chips in the coarse metasandstone - metaconglomerate exposed along St. Marys Bay (Fig. 3b); the long axes of grains parallel the fold hinge. Mud chips define a foliation parallel to cleavage,

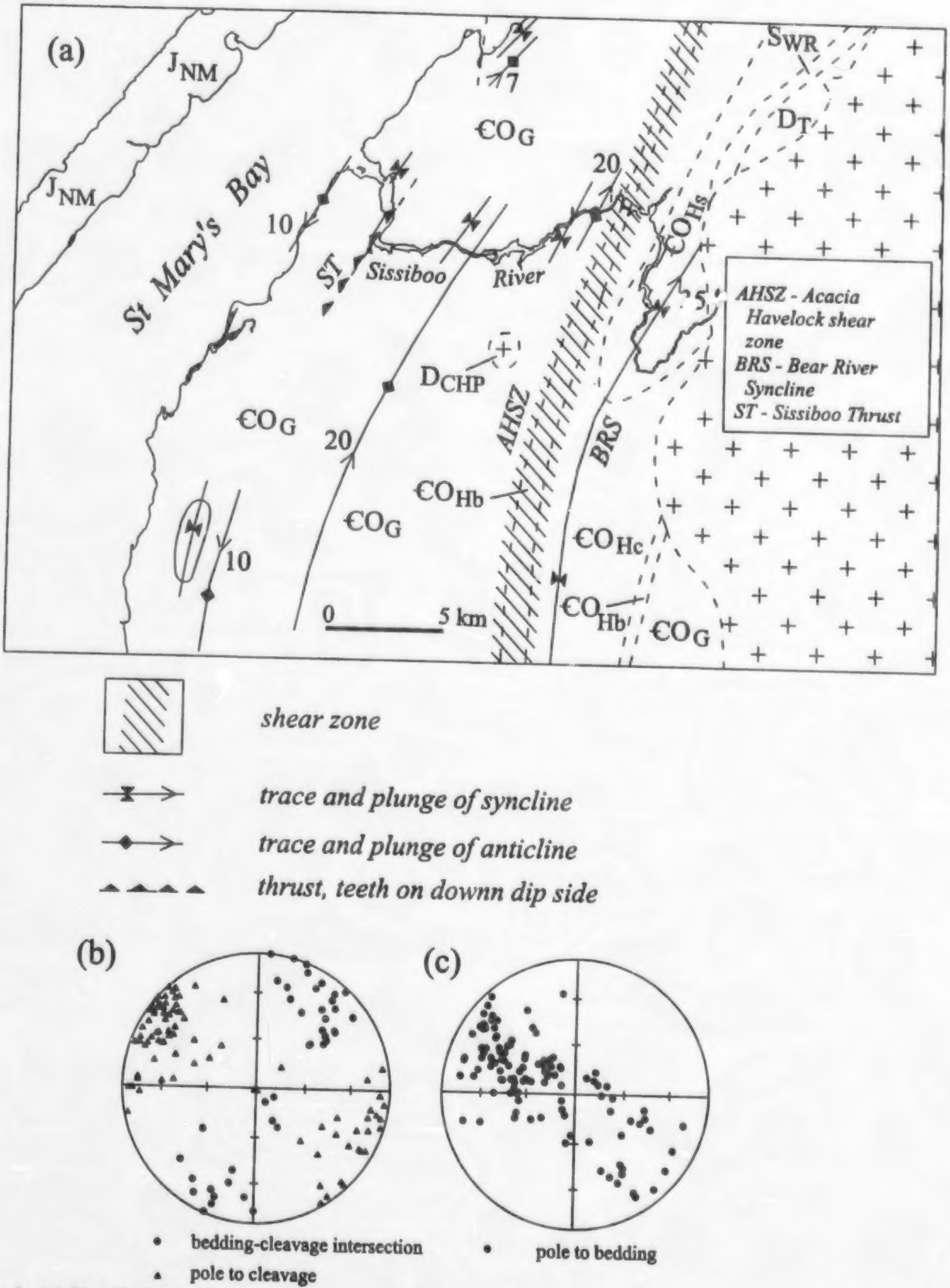

(a)
JNM
JNM
St Mary's Bay
10
ST
Sissiboo
River
€OG
7
20
€OHs
SWR
DT
5
AHSZ - Acacia Havelock shear zone
BRS - Bear River Syncline
ST - Sissiboo Thrust
DCHP
€OG
20
AHSZ
BRS
€OHb
€OG
10
0
5 km
€OHc
€OHb
€OG
shear zone
trace and plunge of syncline
trace and plunge of anticline
thrust, teeth on downn dip side
(b)
(c)
bedding-cleavage intersection
pole to cleavage
pole to bedding

Figure 6. (a) Simplified map of the area showing the distribution of major folds, faults and shear zones. See Figure 2 for legend. (b) Stereoplots of bedding-cleavage intersection and poles to cleavage and (c) poles to bedding for the area. See Figure 2 for legend.

suggesting a fold-related origin for stretching. Concretions in metasandstone beds of the Goldenville Formation also have shapes that are geometrically related to the fold. In profile, concretions commonly have ellipsoid shapes with the long axis parallel to the cleavage plane (Fig. 3d). Many concretions have cylindrical shapes with their long axes parallel the fold hinge; even tabular, bedding-parallel concretions generally have a long axis parallel to the fold hinge (Fig. 3d). These shapes are consistent with fold-related strain, where shortening is perpendicular to cleavage and extension is down-dip and hinge-parallel. Using concretions as strain markers is problematic, as they are highly variable in shape, precluding confident estimates of original shapes. However, consistency in the finite shape of concretions suggests that the apparent flattening and elongation define the axis of fold-related strain.

Metamorphism

Regional metamorphism is within the greenschist or sub-greenschist facies, with cleavage defined by fine-grained mica. Porphyroblasts of biotite, illmenite, magnetite and chlorite overgrow cleavage in metasiltstone and slate throughout the area (Fig. 7a). Pressure shadows on porphyroblasts record variable cleavage-parallel, down-dip strain consistent with folding-related strain. However, the timing of porphyroblast growth with respect to regional deformation and cleavage formation is uncertain.

Well developed contact aureoles occur in the immediate area adjacent to the South Mountain Batholith and the Clayton Hill pluton. These aureoles are defined by biotite±cordierite± andalusite hornfels (Fig. 7b). Similar hornfels zones are locally developed in areas away from the exposed intrusions, notably around Weymouth Falls and Gilberts Cove (Fig. 7c), suggesting buried intrusions in these areas. This interpretation would also provide an explanation for skarns occurring in these areas (see Mineral Occurrences).

Sissiboo Thrust

A thrust fault is proposed in the area west of Weymouth (Fig. 2). The fault is not exposed, but is implied by bedding-cleavage relations in what is interpreted as the hanging wall of the thrust. Specifically, large bedding-cleavage angles (~75°) in slate intervals of the Goldenville Formation are not consistent with the steep dips of bedding in these areas (~75°), but rather imply an origin within a fold hinge. Cleavage is axial planar in slate and metasiltstone intervals of folds in the Meguma Group, generally resulting in small bedding-cleavage angles on fold limbs and large bedding-cleavage angles only in the hinge (e.g. Henderson *et al.*, 1989). This relationship holds even when folds are inclined (e.g. Horne *et al.*, 1998). The bedding-cleavage relations here imply probable thrusting toward the southeast, emplacing a fold hinge area, possibly one exposed to the northwest along St. Marys Bay (Fig. 2), onto a steep fold limb. A similar interpretation was proposed in the Mahone Bay area (Fig. 1) where several thrust sheets representing fold hinge areas are thrust onto the steep limb of the Ovens Anticline (Horne, 1998).

Acacia - Havelock Shear Zone

The Acacia - Havelock shear zone is defined by a wide zone of deformation overprinting the Acadian fold structure. Deformation is characterized by crenulation cleavage (S_2) and minor shear-related folds (F_2) which overprint cleavage (S_1) related to regional folds (F_1). This zone of deformation is confined to the uppermost part of the Goldenville Formation and the lower part of the Halifax Formation (Fig. 2). In the Goldenville Formation shear deformation is restricted to a variably developed crenulation in metasiltstone layers. In the Halifax Formation deformation consists of variably developed crenulation cleavage (S_2), locally defining the principal fabric, and local, minor shear-related folds (F_2; Fig. 8a); S_2 cleavage is axial planar to F_2 folds. The crenulation cleavage and related lineation (L_2; intersection of S_2 and S_1) are regionally constant: S_2 trends north-northwest and dips steeply and L_2 trends south-southeast and plunges steeply (Fig. 8b). Minor F_2 folds plunge steeply, parallel to L_2. The crenulation data and minor fold geometry imply mainly strike-slip faulting with a dextral sense of movement (Fig. 8a, b).

The Acadia - Havelock shear zone is an along-strike extension of similar deformation developed in the uppermost Goldenville Formation and the lower Halifax Formation in the Digby area to the north (Fig. 1; White *et al.*, 1999). The orientations of crenulation data are similar for both areas (compare Fig. 8b here with Fig. 4e of White *et al.*, 1999). The southern projection of the shear zone along the boundary of the Goldenville and Halifax formations extends into the Cranberry Point shear zone of Culshaw and Liesa (1997; Fig. 1b) which is defined by similar features. Culshaw and Liesa (1997) defined several other similar shear zones within the Yarmouth and Cape St. Marys synclines (Fig. 1b) and Culshaw and Reynolds (1997) assigned a middle Carboniferous age (ca. 320 Ma) for this deformation. Recognition of shear zones in the Weymouth (this study) and Digby (White *et al.*, 1999) areas confirms the suggestion of Culshaw and Liesa (1997) of widespread

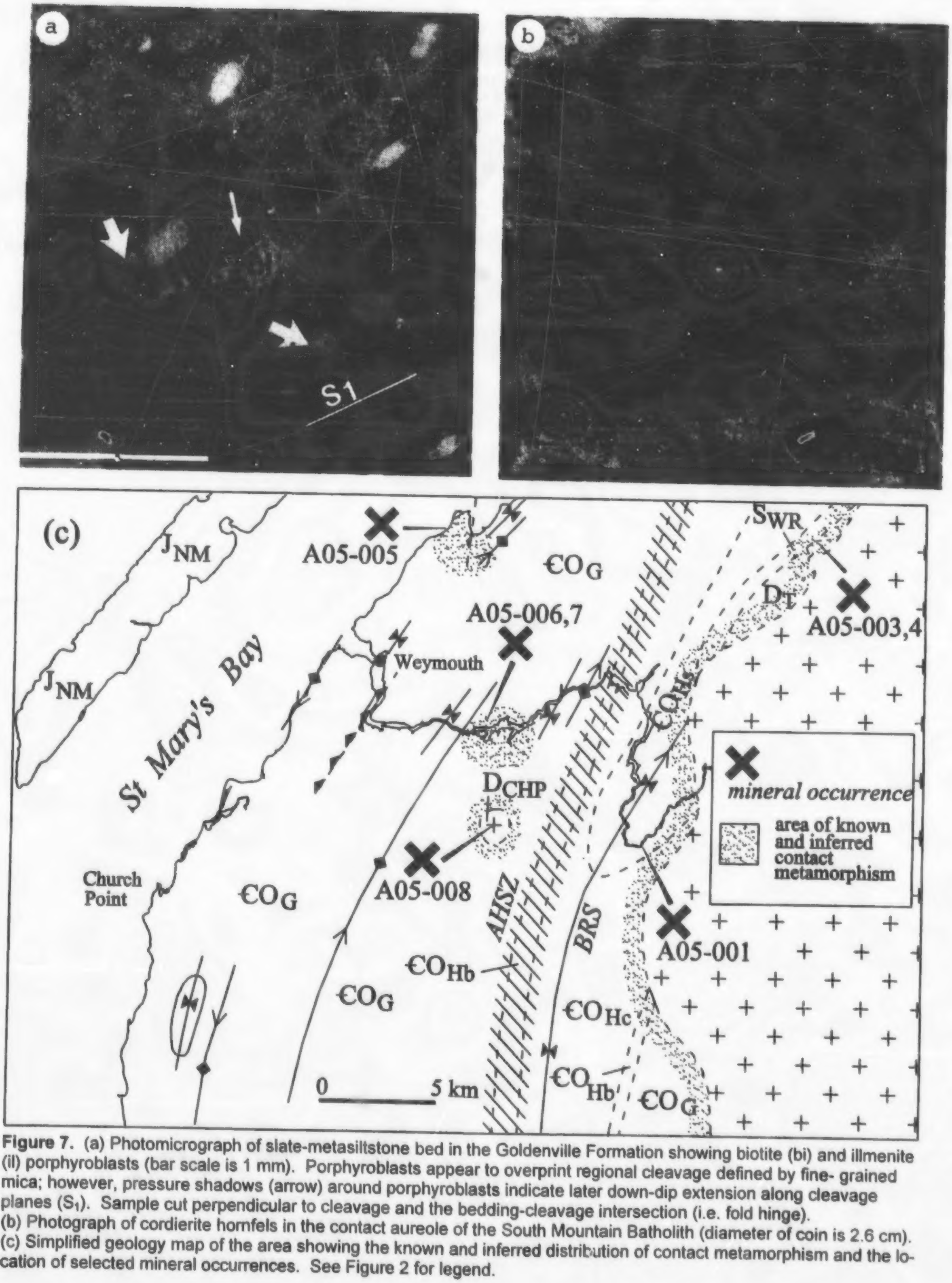


Figure 7. (a) Photomicrograph of slate-metasiltstone bed in the Goldenville Formation showing biotite (bi) and illmenite (il) porphyroblasts (bar scale is 1 mm). Porphyroblasts appear to overprint regional cleavage defined by fine- grained mica; however, pressure shadows (arrow) around porphyroblasts indicate later down-dip extension along cleavage planes (S_1). Sample cut perpendicular to cleavage and the bedding-cleavage intersection (i.e. fold hinge).
(b) Photograph of cordierite hornfels in the contact aureole of the South Mountain Batholith (diameter of coin is 2.6 cm).
(c) Simplified geology map of the area showing the known and inferred distribution of contact metamorphism and the location of selected mineral occurrences. See Figure 2 for legend.

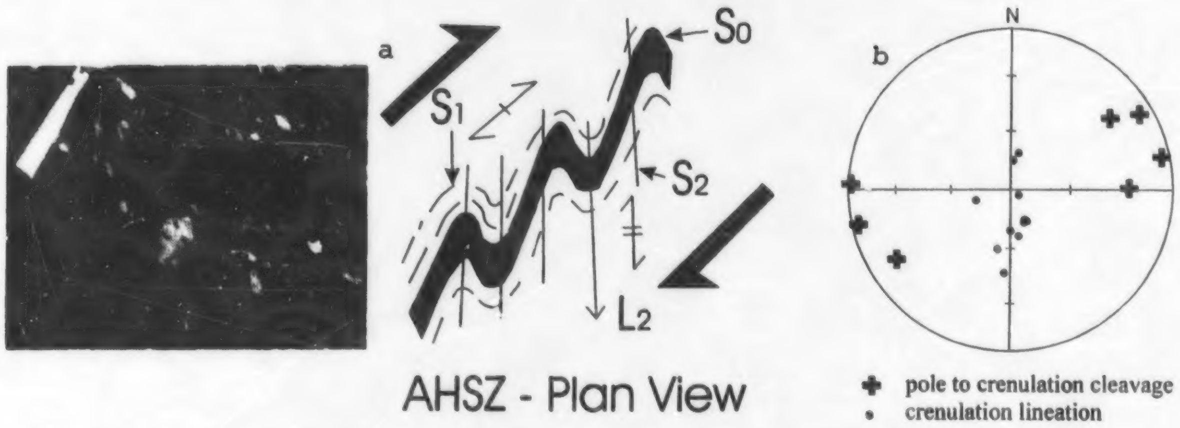


Figure 8. (a) Photograph of minor shear-related folds within the Acacia-Havelock shear zone. Sketch shows the relationship of structural elements in plan view, which suggest mainly dextral strike-slip displacement. S_0 = bedding, S_1 = regional cleavage, S_2 = crenulation cleavage, L_2 = crenulation lineation. (b) Stereoplot of crenulation data for the Acacia-Havelock shear zone.

Alleghanian deformation in this part of the Meguma Terrane. Localization of the shear zone at the boundary of the Goldenville and Halifax formations is interpreted to reflect partitioning of strain at the boundary of competent (Goldenville Formation) and incompetent (Halifax Formation) rock units.

Gilbert Cove Fault

Brittle deformation features, including abundant slip planes, breccia and quartz veins, occur along the west shore of Gilberts Cove (Fig. 2) and the linear shoreline of Gilberts Cove in this area is inferred to reflect a fault. The Gilberts Cove fault is along strike and shows a similar, dextral strike-slip separation (Fig. 2) as a north-trending fault cutting the Triassic-Jurassic rocks to the north (e.g. Keppie, 2000).

Mineral Occurrences

Introduction

Several previously known mineral occurrences lie within the map area, including uranium and limestone near Shortliff Lake (A05- 003*, 004; Fig. 7c) and gold on the Sissiboo River (A05-001; Fig. 7c). In addition, occurrences of copper in the North Mountain basalt, bog iron, diatomite and clay have been reported (see NSDNR Mineral Occurrence Database for NTS map sheets 21A/05 and 21B/08). Following are descriptions of new mineral occurrences found during 1999 field mapping.

New Occurrences

A05-005* Kenny Shore Skarn

Skarn, similar to that at Weymouth Falls (see below), and alteration (bleaching) along bedding planes, are locally developed in concretions in metasandstone beds of the Goldenville Formation exposed along the coast south of Gilberts Cove (Fig. 7c). The skarn locally contains a significant proportion of sulphide minerals and analysis of one sample (B08-99-G001; Table 2) yielded elevated concentrations of silver (2.47 ppm) copper (1700 ppm), zinc (349 ppm), tungsten (95 ppm) and tin (3800 ppm).

A05-006* Weymouth Falls Skarn

Well developed skarn, hydrothermal alteration and late faults are exposed in Goldenville Formation rocks at the spillway built for the Nova Scotia Power hydro-generating plant at Weymouth Falls (Fig. 7a). The skarn is developed within concretions in the metasandstone beds and consists of fine to coarse carbonate and sulphide minerals, including pyrite, pyrrhotite and minor chalcopyrite. Analysis of a skarn sample (A5-99-G002, Table 2) revealed elevated levels of copper (179 ppm), Zn (247 ppm) and tin (240 ppm).

Hydrothermal alteration of metasandstone beds is characterized by bleaching. Alteration typically defines a (tiger) striped colour pattern, where alteration occurs adjacent to fractures. Thin quartz veins occur in some

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* refers to Nova Scotia Department of Natural Resources mineral occurrence number in the Mineral Occurrence Database.

Table 2. Table of geochemical analysis for selected mineralized samples from the map area. Analysis provided by the Minerals Engineering Centre, DalTech Campus of Dalhousie University, Halifax. As and W levels were determined by colorimetric technique and CO_2 by a LECO system. All other elements were determined by atomic absorption.

	WEYMOUTH FALLS			GILBERTS COVE	MISTAKE RIVER	CLAYTON HILL		
	A5-99-G001	A5-99-G002	A5-99-G003	B8-99-G001	A05-ML	A5-99-G004	A5-99-G005	A5-99-G006
Ag (ppm)	0.92	0.03	0.02	2.47	0.01	0.71	0.13	0.01
Au (ppm)	0.005	0.013	0.008	0.013	0.021	0.045	0.023	0.08
Co (ppm)	9	19	12	21	6	2	3	28
Cu (ppm)	1120	179	143	1700	12	173	40	73
Ni (ppm)	49	36	38	54	13	3	3	8
Pb (ppm)	20	10	8	69	9	4	20	8
Sb (ppm)	<2	<2	<2	<2	<2	<2	<2	<2
Zn (ppm)	40	247	88	349	19	68	37	191
As (ppm)	80	25	25	60	540	34	17	5
W (ppm)	1	2	2	95	6	2	3	3
Mo (ppm)	20	2	2	2	3	131	7	3
Sn (ppm)	11	240	2	3800	1	8	9	3
CO_2 (%)	26.20	14.79	1.76	2.06				

fractures; however, veins are relatively rare given the amount of fluid implied by abundant bleaching, which locally accounts for half of the rock volume. In thin section, bleaching can be seen to reflect alteration of biotite to chlorite + titanite, marginal to thin quartz veins (D. Kontak, personal communication, 1999).

The Kenny Shore and Weymouth Falls skarns occur in areas where metamorphism resembles contact hornfels adjacent to intrusions, including biotite-cordierite porphyroblasts. Contact metamorphic features, the significant alteration noted at the Weymouth Falls skarn occurrence, and an elevated granophile element association (Cu, Zn, Mo, Sn, W), all support a probable granite source for mineralizing fluids. Considering the general lack of exposure in the area and the indication of widespread hydrothermal alteration, these occurrences suggest the potential for significant mineral deposits in the area. Regional till geochemistry identified some anomalous concentrations, most notably a >2000 ppm tungsten level in the Gilberts Cove area (Stea and Grant, 1992). Further detailed till geochemistry may be a useful method to locate possible mineralized areas.

A05-007 Weymouth Falls Breccia*

Several discordant brittle faults are exposed in the Weymouth Falls spillway. These faults record minor (1-2 m) vertical displacement and vary in character and thickness along strike, from simple slip-planes to metre-wide breccia zones. The breccia zones commonly have a calcite ± sulphide mineral cement, possibly reflecting remobilzation of carbonates and sulphides from local skarn. The main sulphide mineral is pyrite (marcasite) but minor chalcopyrite and malachite were also noted. Analysis of two samples (A5-99-G001, 3, Table 2) indicated elevated levels of copper (up to 1120 ppm).

A05-008* Clayton Hill Pluton Cu-Mo Occurrence

As mentioned above, boulders of the Clayton Hill pluton are cut by numerous quartz veins which commonly host sulphide minerals, most notably coarse molybdenite, pyrite and chalcopyrite. Several boulders with mineralized veins were located on the new logging road off the west side of Highway 340 and in a gravel pit on the road to Danvers (Fig. 5a). Similar large leucomonzogranite boulders cut by mineralized veins, presumably from the above pit, form a sea-wall at Gilberts Cove. Quartz-muscovite greisen borders are developed adjacent to the veins, and disseminated sulphides locally occur within the granite. Analysis of mineralized samples indicated only slightly elevated levels of copper, zinc and molybdenum (Table 2), although one boulder contained coarse (>1 cm) flakes of molybdenite along the border of a quartz vein with altered leucomonzogranite. The occurrence of numerous mineralized veins and disseminated minerals, including miarolitic cavities, indicates the presence of significant hydrothermal activity which may have resulted in local concentrations of copper-molybdenum. Dakers (1982) reported slightly anomalous copper and silver concentrations in soils over the Clayton Hill pluton relative to the region. The Clayton Hill pluton may be related to the magmatism proposed to be the cause of contact-like metamorphism and mineralized skarns throughout this map area.

A05-009 Mistake River Quartz-sulphide Veins*

Quartz veins occur in bedrock and float along Mistake River north of the Sissiboo River (Fig. 2). These veins contain sulphide minerals, including pyrite and arsenopyrite; one sample yielded 540 ppm As (sample A05-ML; Table 2). Veins occur within the Acacia - Havelock shear zone and are typically deformed (e.g. boudinaged, faulted). The veins include cleaved slate fragments indicating a post-F_1 fold origin, and deformation likely records a sequence of progressive faulting and veining associated with the shear zone.

Summary

The general stratigraphy in the map area is comparable with that defined in the Digby area to the north (White *et al.*, 1999), with the distribution of units controlled by regional folds (e.g. the Bear River Syncline). The Goldenville Formation is the dominant metamorphic unit and, as in the Digby area, has not been subdivided. The Halifax Formation in the map area has been subdivided into three distinct units: (1) the Bloomfield member, which also occurs in the Digby area, (2) the Cunard member, which is interpreted to represent a facies equivalent to the Acacia Brook member in the Digby area, and (3) the Sissiboo member, which is interpreted as a facies equivalent of the Bear River member in the Digby area.

Regional folds are the dominant structure; they trend north-northeast and generally plunge moderately to the north-northeast. A regional-scale shear zone at the boundary of the Goldenville and Halifax formations extends from Digby to the Yarmouth area and is related to widespread middle Carboniferous deformation affecting southwestern Nova Scotia.

Several new and interesting mineral occurrences have been identified in the Weymouth area. In particular, Cu-Mo in the Clayton Hill pluton and skarn at Kenny Shore and Weymouth Falls indicate the widespread occurrence of mineralizing fluids associated with exposed and buried granites and suggest the possibility of economic deposits within the area.

Acknowledgments

Photograph of concretion, Figure 3c, was taken by Howard Donohoe. Geochemical data from mineralized samples were provided by George O'Reilly. Dan Kontak provided comments on mineralization, including the nature of hydrothermal alteration of metasandstone beds at the Weymouth Falls occurrence. We appreciate the comments of a constructive review provided by G. O'Reilly.

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Wall-rock Alteration and Structurally Controlled Mineralization at the Brookfield Barite Deposit (NTS 11E/06), Colchester County, Nova Scotia

D. J. Kontak

Introduction

The Brookfield barite-siderite deposit, located 13 km south of Truro at the east end of the village of Brookfield, is currently being seasonally mined for barite. The deposit was first noted by Fletcher (1892), but exploration and development did not commence until the period 1944 to 1952 and mining at that time was unsuccessful, despite indicated reserves of ca. 100,000 tonnes of high-grade barite (Stevenson, 1951). Following several additional attempts at development, mining began in the 1980s using a combined magnetic separation and flotation procedure to produce pharmaceutical-grade barite. At present the operation produces ca. 5,000 tonnes of barite per year and proven reserves of ca. 25,000 tonnes have been outlined (up to 1999).

The barite deposit is hosted by highly deformed clastic rocks of the Horton Group (Stevenson, 1951, 1958; Felderhof, 1978; Graves 1992) and occurs along the south side of the St. Mary's Graben along the eastern continuation of the Rawdon Fault (Fig. 1). The deposit forms an integral part in the overall metallogenic interpretation of the Carboniferous Maritimes Basin, as the mineralization is considered to manifest the widespread circulation of metalliferous brines ca. 300 Ma (e.g. Ravenhurst *et al.*, 1989; Sangster *et al.*, 1998).

The present study was initiated because of the association at Brookfield of barite, siderite and nearby Fe-Mn occurrences, an endowment similar to that found at many localities along the Cobequid-Chedabucto Fault System, in particular at the past-producing Londonderry Mines. In the course of recent mapping at the Brookfield open pit, several geological features noted had not been recorded by previous workers, in particular the presence of pervasive wall-rock alteration, a complex stratigraphy and obvious structural features controlling mineralization. Thus, the purpose of this paper is to present these initial findings, with the results of continued studies to be reported later.

Geological Setting

The regional setting of the Brookfield barite deposit is shown in Figure 1. The area is located near the contact of terrestrial clastics of the Late Devonian Horton Group and marine carbonates of the Early Carboniferous Windsor Group, occurring within a prominent east-west sliver that is fault bounded to the south by the regionally extensive Rawdon Fault. It is noted that several more faults are probably present in the study area, but they are difficult to follow or delineate because of the limited outcrop. The most prominent exposure of Windsor Group rocks is along the Gypsum Cliffs (Fig. 1) where a thick section of gypsum beds is exposed on a steep slope rising from Little River. Farther west the Windsor Group rocks open into a more extensive area of marine strata (Stevenson, 1958).

At the Brookfield deposit, the Horton Group rocks consist of both the Horton Bluff and Cheverie formations, which Stevenson (1951, 1958) noted are difficult to discern at times. South of the road from the town of Brookfield (Fig. 1), grey siltstone and sandstone dominate. These beds dip to the south and southwest, but change to northerly dips at the deposit and, therefore, define an east-west anticline. Outcrops on the north limb of the fold have facing directions that indicate younging to the north. Along a secondary access road that leads to the deposit area (Fig. 1) this thick sequence of grey siltstone and sandstone (i.e. Stevenson's grits), which resemble Horton Bluff Formation rocks elsewhere on the mainland (e.g. Windsor basin), are overlain by a sequence dominated by fine-grained, red siltstone and shale that eventually excludes any grey beds at the entrance to deposit site (Fig. 2). These rocks are similar to rocks of the Cheverie Formation observed elsewhere on the mainland. This change in rock type, from grey beds to redbeds, is also recorded by a change in facing directions of the strata and the dips of the beds, which are in fact overturned and dip more steeply (to 70-75°) than beds south of the access road (Fig. 2a).

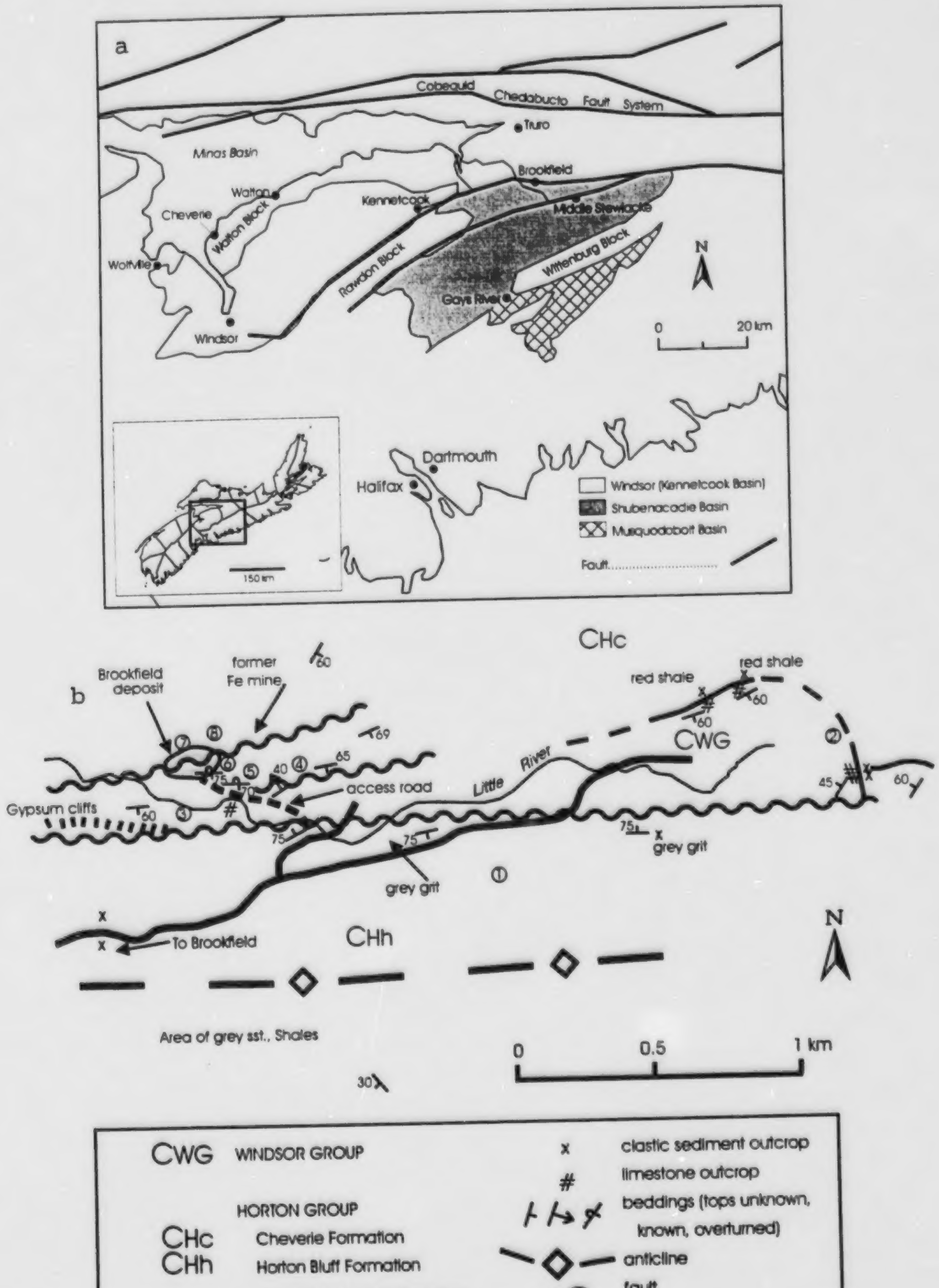


Figure 1. (a) Regional setting of the Brookfield barite deposit. (b) Local geology of the deposit area. Note that the deposit is located just north of a sliver of Windsor Group rocks that are fault bounded to the south. Horton Group rocks south of the deposit are dominated by grey sandstone and siltstone, whereas at the deposit and farther north the rocks are predominantly red siltstone and shale. Numbers refer to sites used for compilation of the schematic stratigraphic section in Figure 3. Local geology modified after Stevenson (1951, 1958).

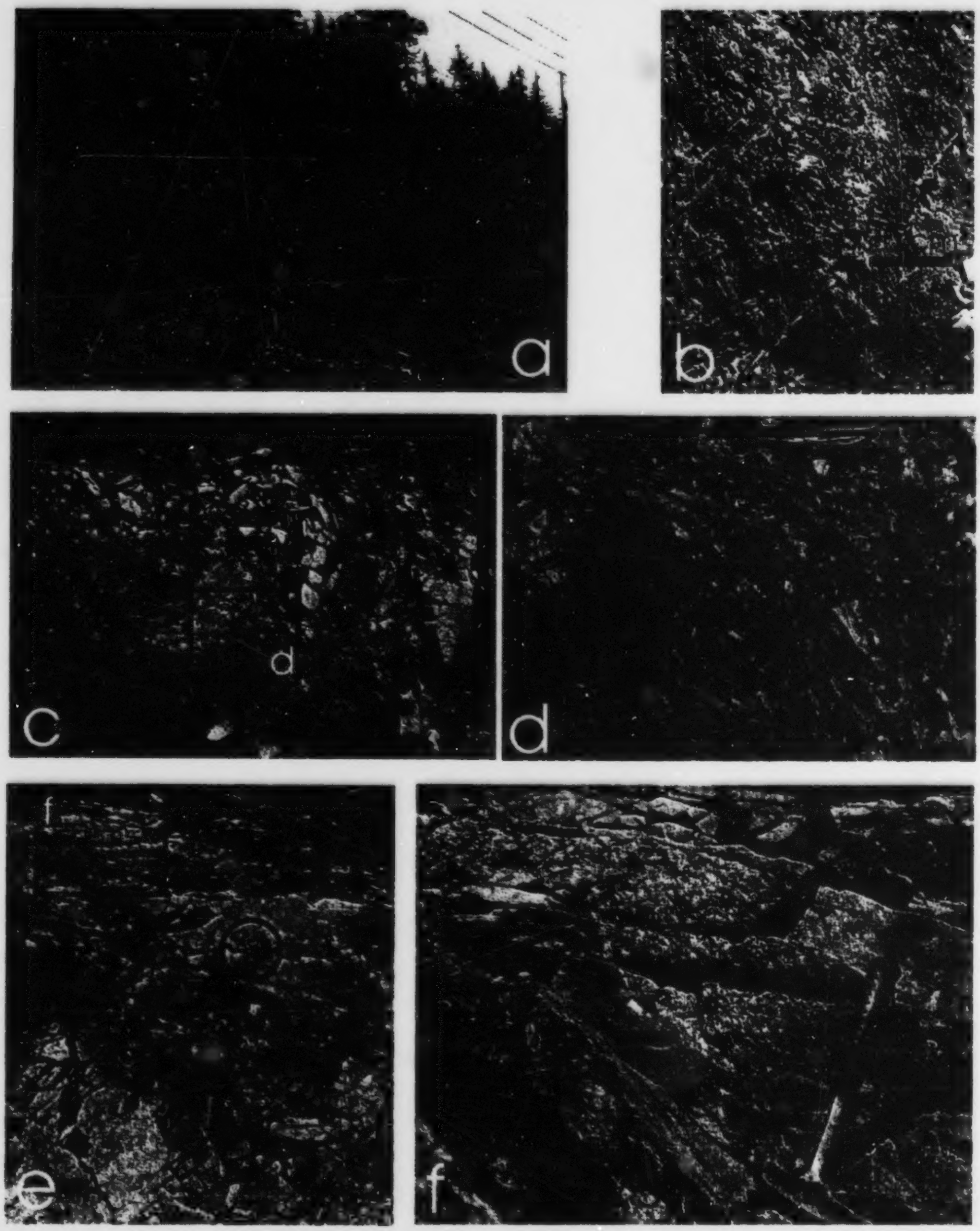


Figure 2. Photographs of various rock types at the Brookfield deposit. (a) Intercalated sequence of red siltstone and shale at the north side of the entrance to the open pit near an old foundation. The beds strike ca. 110° and dip 75° south (to the right), but facing directions are to the north indicating that the beds are overturned. (b) Close-up of the previous outcrop showing well-developed spaced fracture cleavage and narrow veinlets of barite with green alteration haloes. Note knife at bottom of photo for scale. (c) Outcrop of grey, massive siltstone on right in fault (?) contact with highly-deformed, finely laminated grey shale. (d) Close-up of shale in the previous photo. (e) Thick unit of grey sandstone locally with abundant carbonaceous debris and pyrite (light areas in the dark beds). These beds strike to the east and facing directions indicate tops to the south. Note hammer in middle of photo for scale. (f) Close-up of previous photo showing the black, carbonaceous layer with pyrite-rich areas, and the base of the underlying bed with casts, scours and debris.

The area is cut by several east-west faults, which cannot be traced for more than a few kilometres at present because of limited exposure. In addition, the kinematics of these faults remain unknown. Also relevant is the location of this area at the northern, fault-bounded termination of the Shubenacadie Basin (Fig. 1) where several thrusts are shown on regional maps of the province (e.g. Giles and Boehner, 1982). This area is also transected by the regionally extensive Rawdon Fault, a large normal fault with a northerly dip, which changes orientation from northeast-southwest to east-west at this juncture.

Deposit Geology

The geology of the open pit is extremely complicated owing to the fact that several periods of deformation affected the area, including early thrusting and subsequent strike-slip and block faulting. Consequently, only salient aspects of the geology pertinent to the nature of mineralization are discussed in the following section. Further work is continuing in order to more fully resolve the structural evolution of this area.

Stratigraphy

A general stratigraphic column for the area is shown in Figure 3, but it is noted that the paucity of outcrop combined with structural complexity in the area warrants caution with respect to the reliability of this sequence. Numerous low-angle thrust faults have removed some sections and thickened others. The lower sequence is dominated by grey to beige, carbonaceous shale, siltstone and sandstone which, as noted above, outcrop along the access road leading into the deposit area and also dominate farther south on the other side of the sliver of Windsor Group rocks (Fig. 1). The grey beds are inferred to be in fault contact with Windsor Group limestone and evaporites which occur within a fault sliver. The Windsor Group rocks are in fault contact with a monotonous sequence of red siltstone and shale, best exposed at the southern entrance to the pit (Fig. 2a, b) where these rocks are intercalated and bedding (080°/70°S) is clearly seen. The presence of ripple marks and scour structures indicate that tops are to the north, hence these beds are overturned. Within the pit area, and to the northeast where the abandoned Fe mines occur (Fig. 1), there is a sequence dominated by red siltstone and shale with some intercalated grey to buff siltstone and sandstone, which also occurs along the southern part of the pit.

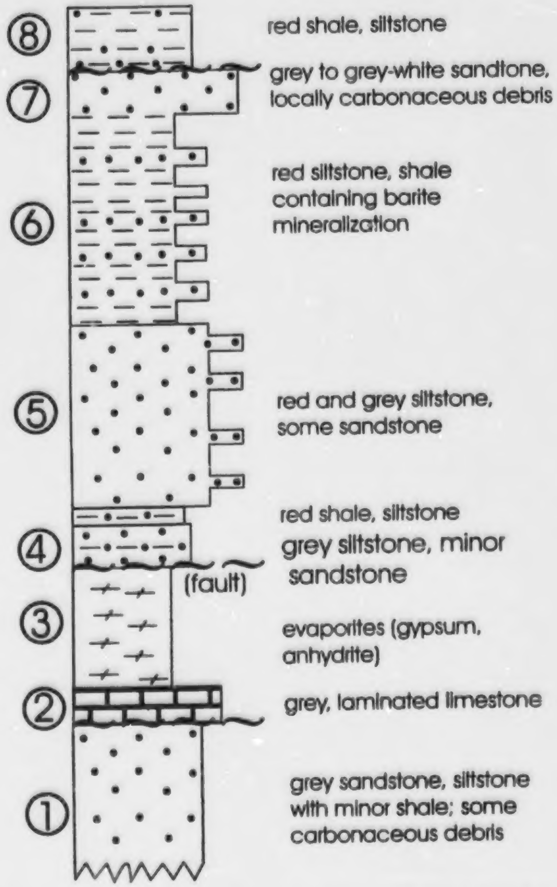

⑧
red shale, siltstone
⑦
grey to grey-white sandtone, locally carbonaceous debris
⑥
red siltstone, shale containing barite mineralization
⑤
red and grey siltstone, some sandstone
④
red shale, siltstone
grey siltstone, minor sandstone
(fault)
③
evaporites (gypsum, anhydrite)
②
grey, laminated limestone
①
grey sandstone, siltstone with minor shale; some carbonaceous debris

Figure 3. General stratigraphy of the area (note that this is schematic only: relative rather than absolute thicknesses are inferred). The numbers on the column correspond to localities in Figure 1b.

The most complete stratigraphic section is found along the northern pit wall (Fig. 4) where, unfortunately, structural complexity occurs. The contacts between most units consist of fault gouge. The following sequence is recognized, from bottom to top.

(1) Red clastics which are in fault contact with an overlying bed of ca. 40 cm thickness of laminated, blue-grey, massive limestone interpreted to be Macumber Formation. This unit is, in part, intensely deformed to a calc-mylonite with intense internal folding (axis sub-horizontal and striking north).

(2) Overlying the limestone is 1 m of grey sandstone and siltstone with calcareous cement locally.

(3) 4 m of red siltstone and shale with variable amounts of green to grey discolouration (alteration).

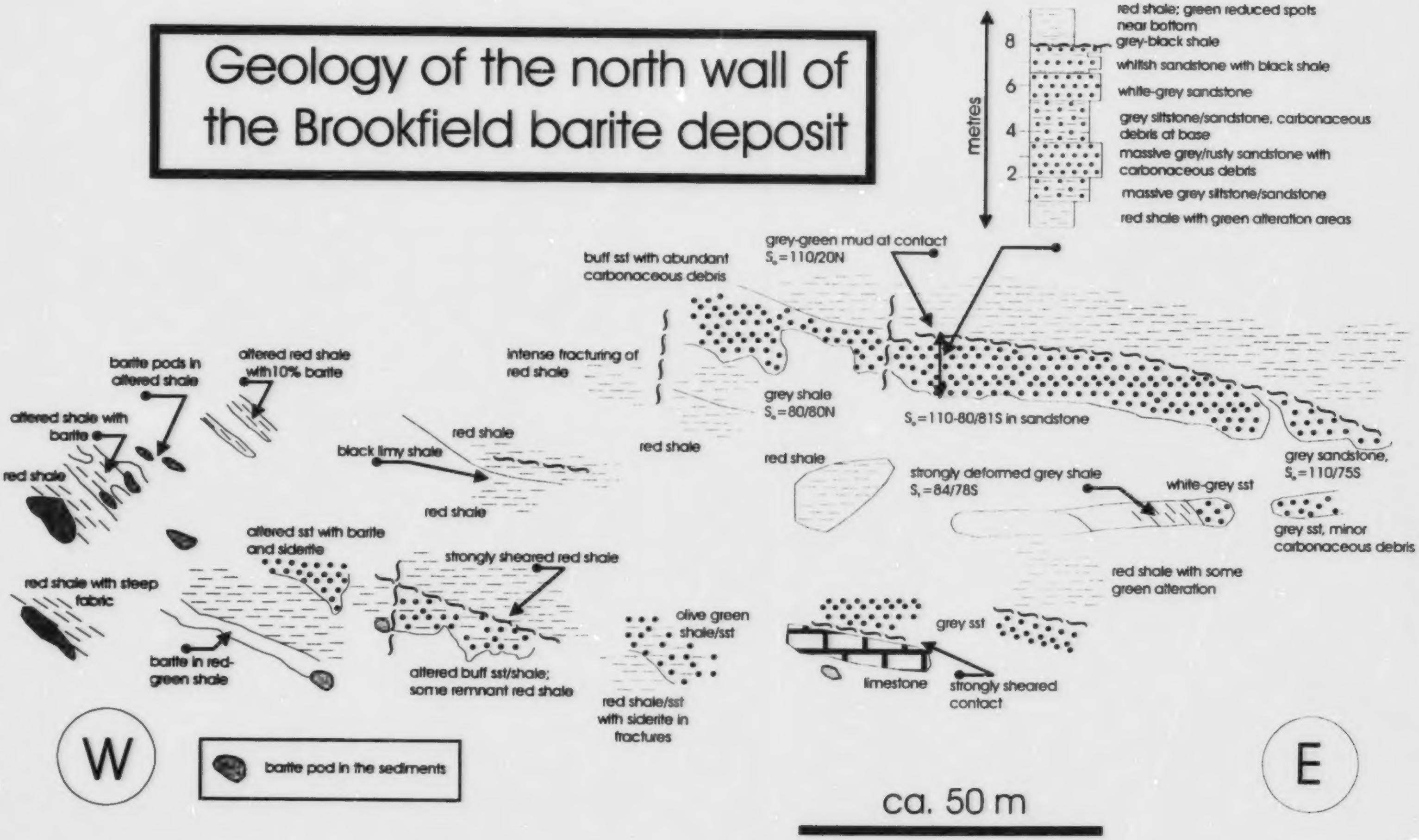

Geology of the north wall of the Brookfield barite deposit
metres
8
6
4
2
red shale; green reduced spots near bottom
grey-black shale
whitish sandstone with black shale
white-grey sandstone
grey siltstone/sandstone, carbonaceous debris at base
massive grey/rusty sandstone with carbonaceous debris
massive grey siltstone/sandstone
red shale with green alteration areas
grey-green mud at contact
S_0=110/20N
buff sst with abundant carbonaceous debris
intense fracturing of red shale
grey shale
S_0=80/80N
S_0=110-80/81S in sandstone
barite pods in altered shale
altered red shale with10% barite
altered shale with barite
red shale
black limy shale
red shale
red shale
red shale
red shale
strongly deformed grey shale
S_1=84/78S
white-grey sst
grey sandstone,
S_0=110/75S
grey sst, minor carbonaceous debris
altered sst with barite and siderite
strongly sheared red shale
red shale with steep fabric
barite in red-green shale
altered buff sst/shale; some remnant red shale
olive green shale/sst
red shale/sst with siderite in fractures
grey sst
limestone
strongly sheared contact
red shale with some green alteration
W
barite pod in the sediments
E
ca. 50 m

Figure 4. Preliminary map of part of the north wall of the Brookfield open pit.

(4) 2 m of grey sandstone/siltstone in structural contact with grey shale (Fig. 2c, d).

(5) 4 m of red shale and siltstone. This unit thins to the east to half this thickness.

(6) 7-8 m of mixed grey siltstone and sandstone with ca. 1 m of red shale with green alteration spots at the base of this section. The grey beds locally contain abundant carbonaceous debris (plant fragments, impressions) and pyrite, which weathers to a rusty brown (Fig. 2e, f). The presence of rip-up shale clasts, graded bedding and scour structures indicate tops to the south at this locality. The upper contact of this section is intensely deformed (Fig. 5) and the grey beds are overlain by 40-50 cm of grey to black shale which grades into green shale and then a thick red shale/siltstone unit that forms the upper part of the north wall (Figs. 3, 4).

Structure

There are three important structural elements in the deposit area. The most penetrative and influential is related to an east- to northeast-trending fault in the area. The second structural element is the presence of early flat-lying thrust faults which pre-date mineralization and modified the stratigraphic section. In many places there are also well-developed, fracture-controlled mineralized zones which presumably relate to the northeast-trending fault. The third element reflects late block faulting, which may be important in terms of exploration since it post-dates barite formation.

Early Thrust-related Structures

Contacts between many stratigraphic units are marked by generally flat-lying zones of highly deformed rock resembling fault gouge. These zones, generally 1 to 10 cm thick and undulating, commonly occur between relatively competent and incompetent beds such as shale and siltstone or sandstone (Fig. 5a, b). As noted previously, the north wall of the open pit exposes many such contacts between units. Not all thrusts are parallel to bedding, as exemplified by a shallow thrust that cuts across bedding and transports red siltstone over several stratigraphic units (Fig. 5c, d). The overall configuration of the thrust slices is probably a ramp, as suggested from the shape of a few of the better displayed thrust packages. In most cases there is an absence of striations on fault surfaces, which precludes determining the sense of movement. However, in a few locations such striations indicate a general north-south movement, perpendicular to the strike of the beds.

Structures Related to the Northeast-trending Fault

The major structural elements in the deposit area reflect the influence of a northeast-trending fault (Fig. 1). Planar measurements (bedding, spaced cleavage, fractures) reflect the presence of this dominant structural element. Bedding varies considerably due to folding and rotation of beds as a consequence of faulting, and there is a change in the orientation of bedding from south of the deposit area (40° to 50°) toward the mine (70° to 100°). Assuming that this rotation of bedding is fault related, it indicates dextral movement of the fault. Bedding measurements also define a girdle array on a stereoplot (Fig. 6a) and indicate folding about an east-trending, shallowly plunging (10°-15°) axis. This orientation is similar to the orientation of minor folds seen in the open pit, which all have fold axes with east-west orientations and shallow plunges.

A spaced fracture cleavage is variably developed within the shale beds, but its orientation is highly variable. Within an area of approximately 1 m^2 several different orientations can be observed (Fig. 6b), whereas in some places a consistent pattern is present (Fig. 2b). The cleavage shows variable spacing of ca. 2-5 mm. In general, cleavage development relates to the pervasive development of a northeast-trending fracture pattern, which is related to the northeast-trending fault that transects the area.

Fractures are locally abundant and although orientations of multiple sets may be consistent in a given area, collectively within the pit there is considerable variation even though there appears to be a dominance of steeply dipping, northeast-trending fractures (Fig. 6c, d). Further work on a more detailed scale is planned in order to evaluate the use of these fractures as kinematic indicators of fault movement. The fractures are important with respect to fluid flow and mineralization, since alteration and mineralization are fracture controlled in many cases (Fig. 7 and below).

Late Block Faulting

The last structural event recognized displaces strata along subvertical, north-trending faults. These are well exposed between the contact of the red siltstone/shale package and the underlying grey to grey-white sandstone. Offsets are ca. 1-2 m in the vertical dimension and the blocks are several metres wide, but the amount of lateral offset remains unknown. There appears to be a gradual stepping down from east to west in the central part of the pit, such that the grey sandstone-red shale contact is downthrown along this

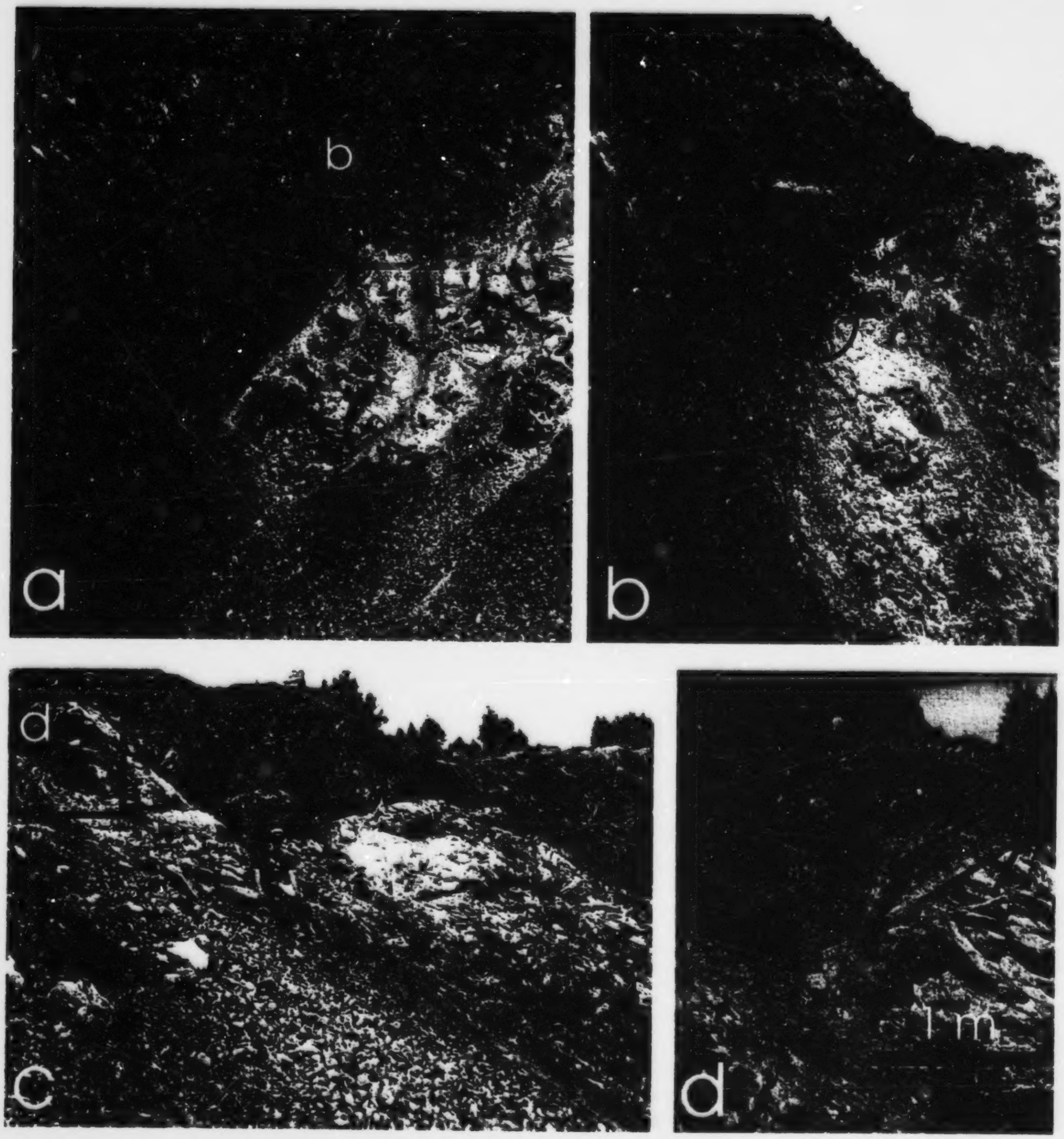
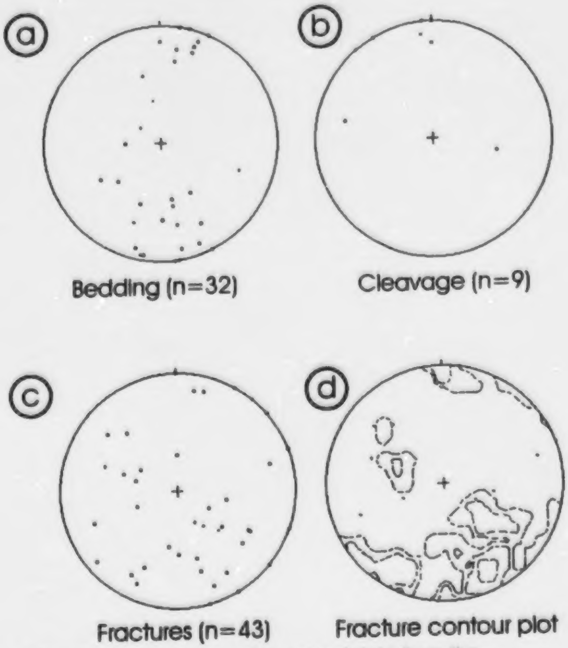


Figure 5. Photographs taken within the open pit at Brookfield showing structural features. The dashed line in Figures 5b and 5d indicate the trace of flat-lying faults (i.e. the early thrusts). (a, b) Northeast face showing structural contact between overlying thick sequence of red siltstone and shale (100°/60°S) and massive grey siltstone section beneath (140°/40°NE). Note circled hammer for scale in Figure 5b. The massive grey sandstone unit here is the same as in the centre of the north wall shown in Figure 4 and in the following photos. (c, d) North face of the open pit showing structural contact between massive grey to grey-white sandstone below and overlying red siltstone. Contact is a dark grey to grey-green fault gouge rock. In Figure 5c note that the abrupt change in the trace of the fault zone relates to vertical offset of the fault by later block faulting.



Bedding (n=32)

Cleavage (n=9)

Fractures (n=43)

Fracture contour plot

Figure 6. Stereoplots of structural data from the Brookfield barite deposit area. (a) Poles to bedding outlining a girdle which indicates a shallow-plunging fold to the east. (b) Poles to cleavage in shale sections. (c) Poles to fractures, some of which contain barite and/or alteration haloes. (d) Poles to fractures in Figure 6c contoured.

strike direction (Fig. 5c). However, the prominent grey sandstone unit at the east end of the pit suggests that this part of the deposit area has been upthrown relative to the central part. These offsets are important for mine development since the ore zone may in fact be offset beneath the present working level at the east end of the open pit and more work is required to fully evaluate this possibility.

Alteration and Mineralization

Fractures at the Brookfield barite deposit are commonly filled with barite and/or siderite and have narrow, green alteration halos which contrast with the red colour of the host siltstone or shale. These fractures (Fig. 7) mimic the orientation of the spaced cleavage in some cases, but many orientations appear to be random. In any one particular area, one or two orientations appear to dominate. Where there is an abundance of sub-parallel fractures filled with barite, the veins are similar to a sheeted stockwork system. Areas with well-developed fractures filled with barite and the associated alteration appear to form a halo about the massive barite zone. The farthest these veins have been observed away from main zone of mineralization is at the entrance to the mine site, where there is a network of barite-filled fractures (Fig. 2b).

The open pit is dominated by a red shale/siltstone sequence; however, green or grey coloration is common within these beds and is best developed where barite occurs, suggesting that it is related to the mineralizing process (Fig. 7). It is important to note that previous workers (Stevenson, 1951; Felderhof, 1978) noted a preference of barite with grey-green shale beds intercalated with red shale, but no previous workers have suggested this was related to alteration. Although there is minor development of this discoloration outside of the mineralized zone, the degree to which it forms is closely related to the abundance of barite. Where barite veins are isolated, it is possible to see a green to green-grey alteration halo 1 to 3 cm wide parallel to the vein; hence, there is clear evidence that formation of this discoloration is directly related to barite mineralization. Where multiple veins of barite occur, the rock is converted to a green-grey colour.

Red siltstone or shale may occur as (1) isolated fragments within alteration zones or (2) coring mineralized areas with a green outer margin and borders of siderite between the barite and altered wall rock. Both types of occurrence are excellent examples of alteration (Fig. 8). In sections of red siltstone the rock may be converted to pale red or grey as a result of alteration, but this is less common than the alteration referred to above. The presence of boulders in the pit showing this alteration indicates that it is also present in the area of active mining.

Barite Mineralization and Paragenesis

Barite is the main ore mineral in the mine area, with minor to trace siderite and quartz associated with it. In a few localities late, cross-cutting veinlets of calcite occur which post-date alteration of the red shale. The types of barite occurring within the pit, based on mapping and examination of debris from the mining operation, are listed below.

(1) Coarse white barite occurs with elongate crystals (Fig. 8b) oriented parallel to each other in large boulder samples. Unfortunately this has not been seen in outcrop, hence crystal orientation in not known. However, in a few large boulders the coarse crystals are oriented parallel to the vein-wall rock contact, suggesting they may be subparallel to the fault. This type of barite is the most abundant in the area.

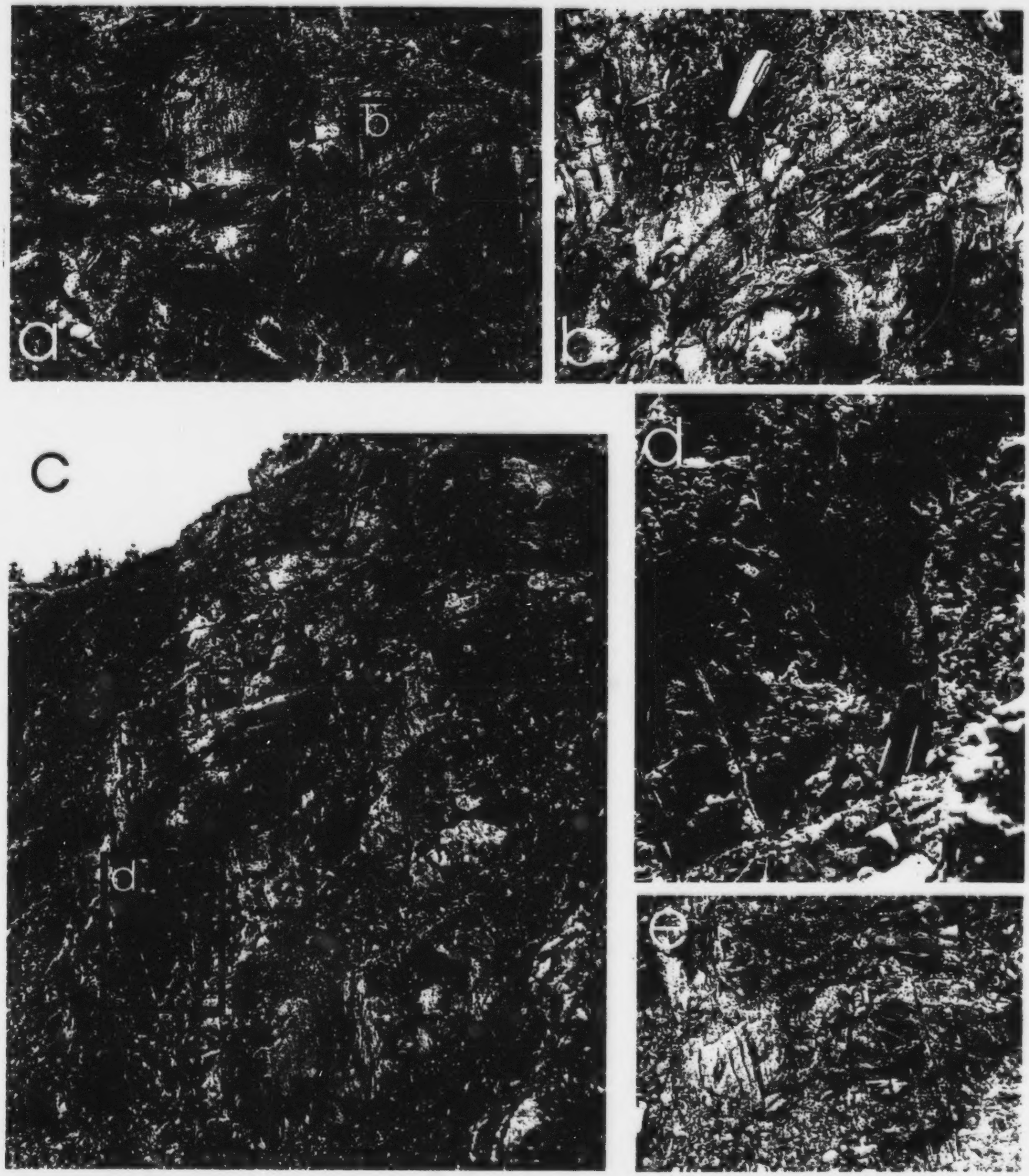


Figure 7. Photographs illustrating the intense alteration in redbeds at the Brookfield barite deposit. (a, b) Green alteration halo developed around generally flat-lying to gently dipping fractures filled with barite. Note pen knife for scale in Figure 7a (circled). (c, d) Development of green alteration haloes at various scales associated with steeply-dipping fractures. In this particular case there is very little barite associated with the alteration. (e) Intense development of green alteration halo about sub-vertical to sub-horizontal fractures filled with siderite. Note that about 60-70% of this outcrop has been bleached by the alteration.

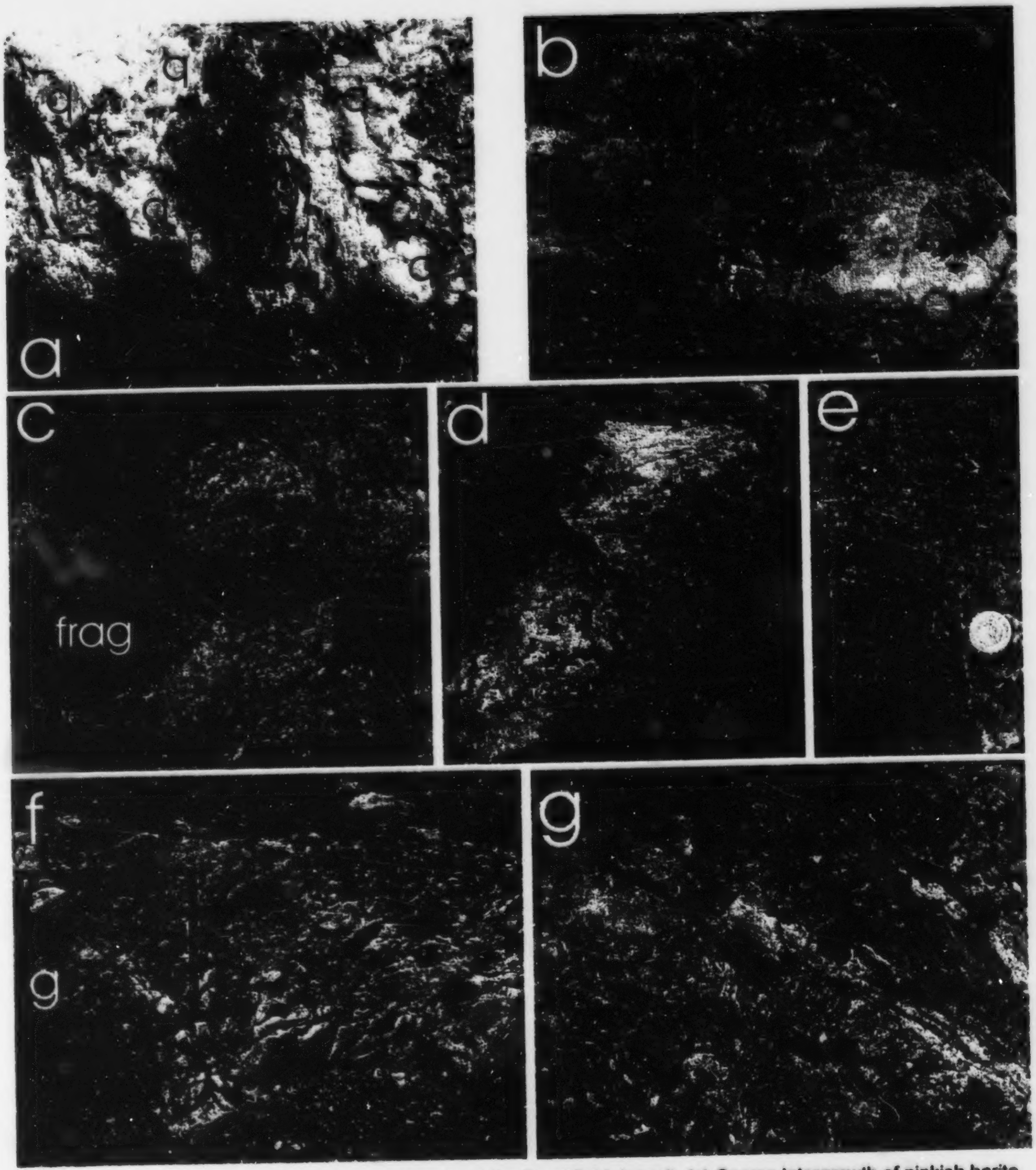


Figure 8. Photographs of the different types of barite at the Brookfield deposit. (a) Coarse intergrowth of pinkish barite, euhedral quartz (q) and siderite (dark). (b) Large boulder of coarse, white barite (note large crystal faces on top of loonie) with siderite (dark). The barite crystals are elongate and are all sub-parallel to the fabric defined by layers of siderite. (c) Medium- to fine-grained crystalline barite with green shale (alteration) as the wall rock. Note the fragment of green shale incorporated into the vein. (d) Vein of coarse white barite with narrow band of siderite at the contact with altered, bleached wall rock shale. (e) Fine-grained, pinkish-white barite with distinct planar fabric defined by thin layers of siderite. (f, g) Outcrop of white to orange barite vein in variably altered red-green shale at west end of the north face of the open pit. Close-up photo shows thin layers of siderite in the barite and this banding is sub-parallel to bedding in the host rock.

(2) White barite also occurs intergrown with siderite. The siderite appears to post-date barite and occludes the remaining open space (Fig. 8b). A variation on this occurs where coarse siderite euhedra are aligned along a plane as if infilling a late open structure in the barite. This is probably related to type 1 barite and is also best developed in the area of most abundant barite mineralization. In rare cases coarse barite veins cutting red siltstone/shale have a border of siderite along the vein contact (Fig. 8d).

(3) Massive to crystalline, orange barite is common in the margin areas of the mineralized zone where it occurs in the red siltstone and shale sequence (Fig. 8c). In such areas it is common to see remnant wall rock that has been altered to green shale within the barite, although remnant cores of red shale are sometimes present. This barite locally contains layers of siderite with a planar orientation sub-parallel to the local bedding (Fig. 8f, g). Rare cases of grey limestone within barite have also been observed.

(4) Laminated barite is seen in areas where barite occurs within the red sediments, but the best examples are seen in isolated boulders (Fig. 8e).

(5) Ultra fine-grained orange barite is rare, consequently its relationship to the other types of barite remains ambiguous.

(6) Disseminated barite in sandstone is locally developed where rocks have been altered and proximal to barite.

The paragenesis of the Brookfield deposit is simple, consisting of near synchronous formation of barite, siderite and quartz in conjunction with alteration of the red clastic sediments. Most of the siderite and quartz appear to occlude open space, thereby indicating a slightly later timing relative to barite. The presence of altered wall rock cut by siderite and barite veinlets indicates that deformation and vein formation were ongoing processes.

Discussion

Results of recent mapping of the Brookfield open pit indicate that abundant and pervasive wall-rock alteration accompanied the barite mineralization. This alteration, in the form of a green to grey-green discoloration of the host red siltstone and shale, was structurally controlled and occurred along a variety of fracture directions. In many cases, barite cores the fractures with alteration envelopes symmetrically disposed about the veins; hence, barite mineralization and alteration appear to be genetically related. In addition, siderite commonly occurs between the barite and altered wall rock, which also indicates a genetic association.

Several structural elements have been recognized in the deposit area. The oldest is a flat-lying ramp or thrust that is generally parallel to bedding. This early structural event resulted in a horizontal stacking of the strata and in many cases contacts between units are represented by fault gouge. Subsequent to thrusting, dextral movement along a major east-west fault affected the area, resulting in a steepening of the bedding, locally overturning it, and also causing minor folds with sub-horizontal, east-west axes. The last structural event was sub-vertical block faulting with offsets of 1-2 m in the vertical dimension, but unknown lateral displacement.

The barite appears to be structurally controlled and to represent both open-space infilling and replacement styles of mineralization. In the former, the coarse, bladed crystals are sub-parallel and may reflect the orientation of the fault structure. The lack of comb textures or crack-seal laminations indicates a single vein-opening event. The nature of siderite and quartz indicate occlusion of open space after initial formation of barite. Finer grained, commonly orange to pinkish-white barite occurs as massive, irregularly-shaped pods and lens within the red sediments, but with associated alteration. This type of barite may have formed from replacement of the host rock. The very fine-grained barite, often displaying a conchoidal fracture, and the laminated barite may reflect recrystallization during deformation under conditions of high strain.

The conditions of barite formation remain to be fully constrained, but Ravenhurst *et al.* (1989) reported fluid inclusion temperatures of 220 ± 10°C and high salinities (ca. 25 wt. % equiv. NaCl) that are similar to fluids associated with mineralization in the basal Windsor Group (Sangster *et al.*, 1998). Sulphur isotope data on barite, also reported in Ravenhurst *et al.* (1989), are consistent with a sulphur reservoir in the Windsor Group evaporites. In order to better define the nature of mineralizing fluids and determine the ambient pressure of formation, additional fluid inclusion work is planned.

Finally, it is interesting to note that the Scotsville barite deposit, located at the northern end of Lake Ainslie on Cape Breton Island, has some distinguishing features that are similar to those seen at Brookfield. The deposit occurs within a fault zone cutting red clastics of the Horton Group and similar wall-rock alteration occurs. Continued work at this site will permit a comparison of barite formation between the two areas.

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Nature of Zeolite Distribution in the North Mountain Basalt, Southern Nova Scotia: Field and Geochemical Studies

D. J. Kontak

Introduction

Recent interest in the commercial development of zeolites in the Jurassic North Mountain Basalt (NMB) of the Annapolis Valley area, Nova Scotia, has focused attention on this world-class zeolite locality (Marshall, 1999). Although most world zeolite production is from altered tuffaceous rocks (pyroclastics), the abundance of zeolites in certain parts of the North Mountain Basalt has been recognized and the potential for a commercial zeolite industry in Nova Scotia may soon be realized. The dominant zeolite minerals in the NMB (Pe-Piper and Horton, 1996; Pe-Piper, 1997; and references therein) include types (e.g. heulandite, mordenite, stilbite) that have traditionally been mined and are commercially favored. In order to commercially develop any commodity, an adequate understanding of the distribution and properties of the commodity is a prerequisite. In fact, given that a considerable price difference exists for zeolite types, it is not only important to understand their distribution, but also the occurrence of each type. The present study focuses on addressing these important questions.

Although previous work on the distribution and types of zeolite within the North Mountain Basalt was recently summarized by Pe-Piper and Horton (1996), there is no detailed study of the actual distribution of zeolites within flows, nor a theory as to what controls this, although earlier observations (Hudgins, 1960; Aumento, 1962; and references therein) indicate that a zonal distribution occurs. Given that such information relates to potential development, this project focused on the distribution of zeolites within basalt flows. In order to determine what controlled zeolite distribution, outcrops of NMB were examined along the southern side of the Bay of Fundy from Scots Bay to Victoria Beach (Fig. 1). In addition, subsequent follow-up studies, including detailed petrographic and electron microprobe analysis, revealed new information regarding the nature of the zeolites, their distribution within the basalts, mineral paragenesis, and processes responsible for zeolite formation. In this paper, initial results on the distribution of zeolites and their genesis are presented. Studies pertaining to the thermal conditions of formation and nature of the mineralizing fluids are continuing and will be reported on at a later time.

Field Relationships and Observations

The North Mountain Basalt (ca. 10,000 km^2; Colwell, 1980; Greenough and Papezik, 1987) was deposited ca. 202 Ma (Hodych and Dunning, 1992) in the Bay of Fundy graben and forms part of an extensive Mesozoic basalt province along eastern North America. Basalts of similar age and composition along this basalt province were also deposited in small rift basins in response to lithospheric extension accompanying opening of the Atlantic Ocean. The NMB, which forms a prominent topographic high along the northern margin of the Annapolis Valley, dips northwestward (3-10°) and varies from ca. 400 m thick at Digby to ca. 275 m thick near Cape Split. Basalt, part of the Fundy Group, is underlain by continental red conglomerate and sandstone (Wolfville Formation) and siltstone and shale (Blomidon Formation). Unconformably overlying the basalt are lacustrine limestone, calcareous sandstone and time equivalent continental clastic rocks (Scots Bay Formation).

The internal stratigraphy of the North Mountain Basalt, as described by Papezik *et al.* (1988), consists of three main units (but note that Colwell, 1980, gives a slightly different description): (1) a lower, massive flow, 190 m thick at Digby to 50 m thick near Cape Split, which is medium- to coarse-grained; (2) a middle unit, up to 50 m thick, composed of a series of thin amygdaloidal lavas; and (3) an upper, massive unit of phenocryst-rich basalt which is about 160 m thick near Digby. On the north shore of the Bay of Fundy four thin flows totalling 74 m comprise a fourth unit which underlies the basal unit (1) mentioned above (Greenough *et al.*, 1989).

The North Mountain Basalt was examined at several localities along the coastline and inland (Fig. 1), but given the excellent exposure along the coast most of the data collected came from such localities. At the coastal

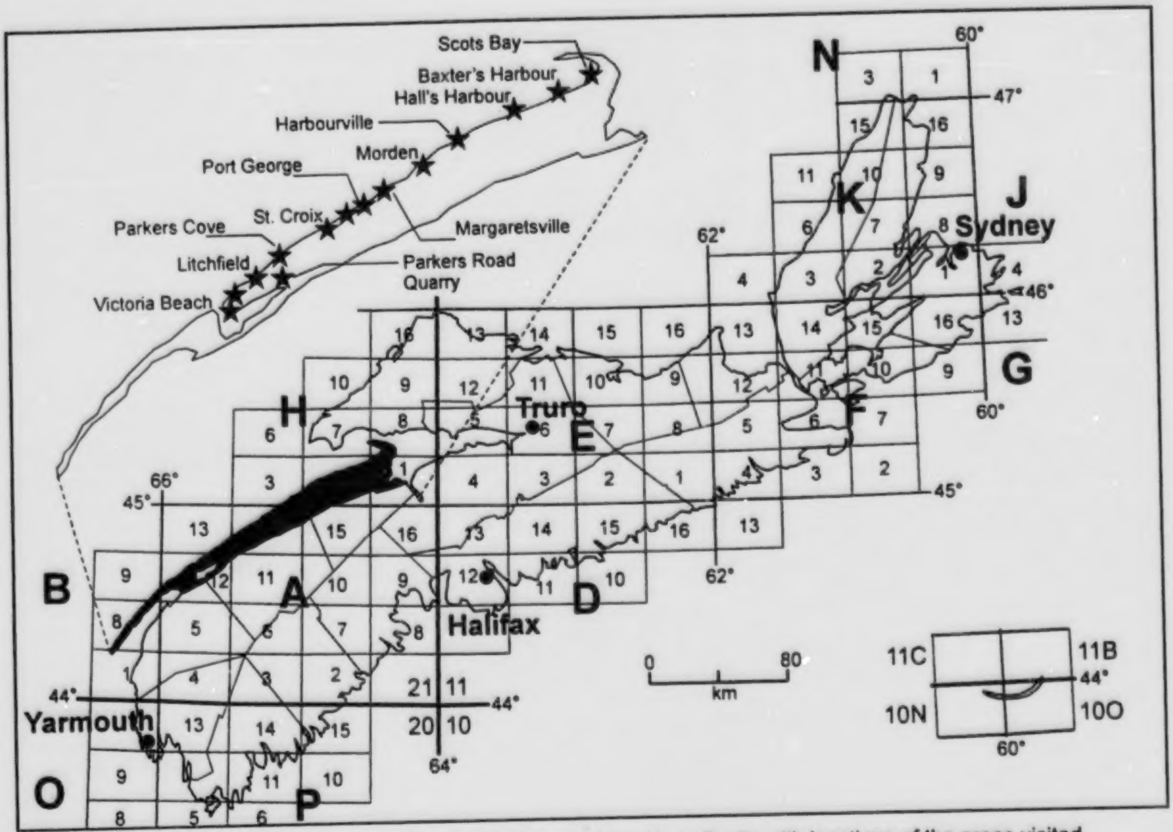

Figure 1. Outline of the North Mountain Basalt (black) in southern Nova Scotia with locations of the areas visited.

stops, traverses of several kilometres were made and particular note was taken of the number of flows and the distribution of zeolites both vertically and laterally. Despite the limited vertical and lateral continuity of inland outcrop, the features of the basalt are similar to those examined along the coast, thus similar conclusions are made.

Individual flows observed are generally ca. 8-10 m thick (rarely to ca. 20 m) and this is uniform for considerable distances where flows could be followed along coastal sections; the exception to this was noted at the Parker Cove quarry near Annapolis Royal where a single flow >100 m thick is exposed. Flows generally have a flat to slightly inclined dip, indicating a flat paleotopography during volcanic activity in the areas examined. The contact zones between flows are sharp, but rare cases of irregular surfaces have been observed, including 1-2 m depressions or gullies and corrugated tops (Fig. 2). A distinct reddening occurs in the top 1-2 m of some flows (Fig. 2d), which is presumed to relate to oxidation.

The flows are variable in their texture with massive, isotropic flows the most common. The basalt is generally dark grey-green and fine grained with plagioclase laths and an ophitic texture visible in the coarser-grained parts of flows. Within a flow the texture is uniform, except with notable chilling seen towards flow bottoms. The only additional textures observed were amygdules; there were no xenoliths, pegmatites, interflow sediments or felsic lenses, features that have been observed elsewhere in the North Mountain by previous workers (e.g. Greenough and Dostal, 1992b, c; C. White, personal communication, 1999).

Fractures (flat, vertical and circular) are locally common and these features are described here because of their importance in providing porosity and permeability in the basalt for zeolite formation. Flat fractures may occur randomly throughout a flow (Fig. 2e) or dominate the upper half, with fracture density progressively increasing toward flow tops (Fig. 2c, d). The interval between fractures is commonly 10-20 cm and fractures rarely continue for more than a few

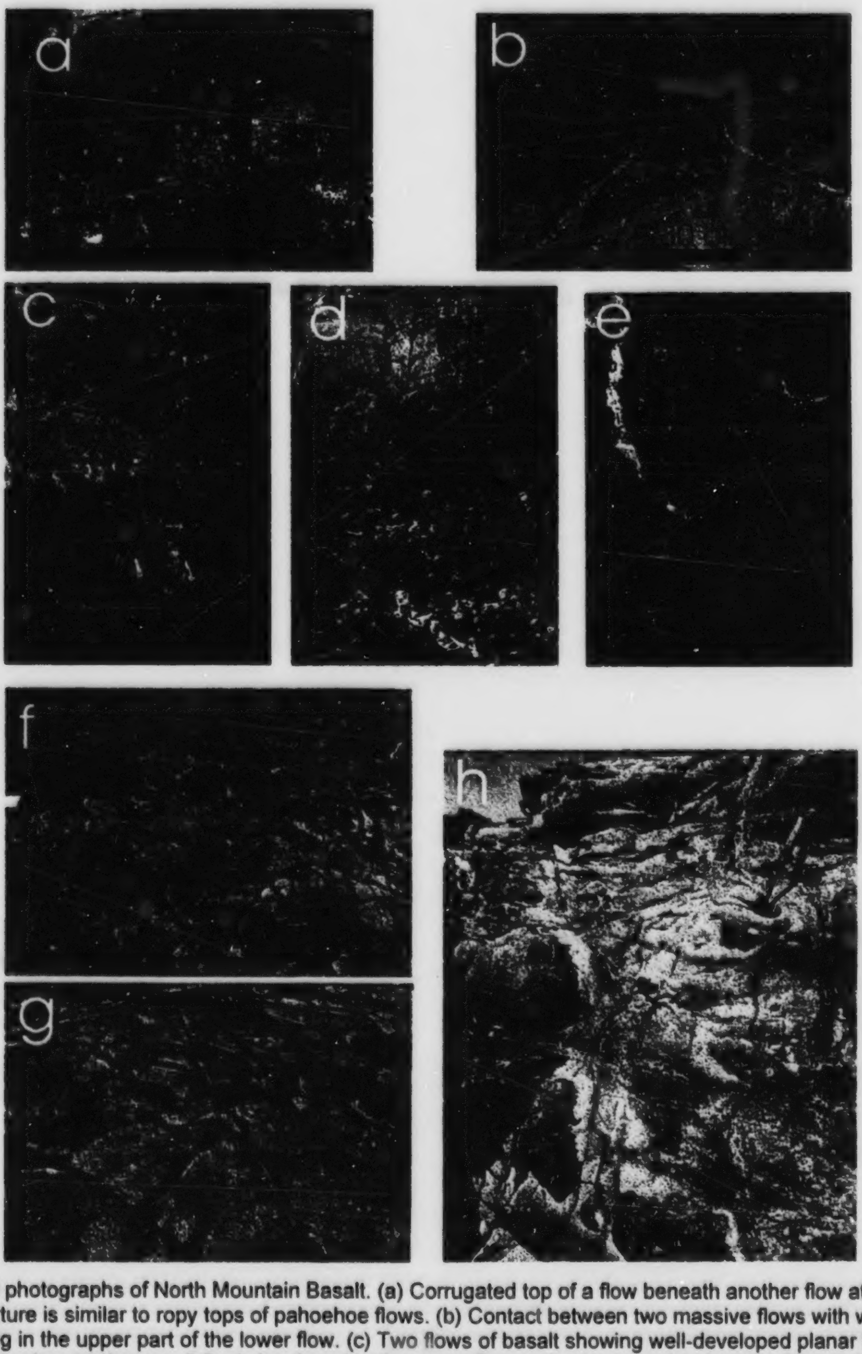

Figure 2. Field photographs of North Mountain Basalt. (a) Corrugated top of a flow beneath another flow at St. Croix Cove. This texture is similar to ropy tops of pahoehoe flows. (b) Contact between two massive flows with well-developed planar fracturing in the upper part of the lower flow. (c) Two flows of basalt showing well-developed planar fracturing. Note the very regular spacing (ca. 0.5 m) developed in the upper flow and more irregular density of fracturing in the lower flow. (d) Irregular fracturing in basalt flow with remnant areas of massive texture (no fractures) preserved. (e) Columnar jointing in basalts along the coast at Port George. (f) Columnar jointing in basalt with incipient alteration along the joints. Note the circle around hammer for scale. (g) Close-up of triple junction in columnar jointed basalt showing alteration along the joints and later infill by fine-grained silica. Knife is shown for scale. (h) Large-scale development of spheroidal weathering in basalt.

metres before coalescing with other fractures (Fig. 2e). One of the most conspicuous and common structural features is the development of vertical columnar jointing (Fig. 2f), best observed between Margaretsville and Litchfield in what may be the same flow. The scale of the joints is exceptionally consistent with columns having a width of ca. 1 m. Locally, alteration along the columnar joints imparts a positive relief and enhances the columnar pattern (Fig. 2f). Alteration zones are also developed parallel to these fractures and often vein silica infills fractures (Fig. 2g; also see below). Vertical fractures, in a generally N-S orientation, also occur and these fractures may traverse an entire flow.

Spheroidal weathering is a common feature of areas where well-developed fractures occur. This weathering creates areas of basalt dominated by a bulbous shape with diameters of ca. 0.5 to 1 m. This feature may be mistaken as being a pillow-like structure, but lacks the typical interconnecting concave-convex patterns and tear-drop bottom structures that characterize pillow basalts. The spheroidal weathering is merely a manifestation of preferential weathering along intersecting fracture patterns, in this case flat (horizontal) and vertical fractures that are locally developed in the basalt (Fig. 2h). Hudgins (1960) came to a similar conclusion regarding these features.

The basalt has been subjected to two distinct, but temporally and spatially related, hydrothermal events that deposited zeolite minerals and silica. Whereas the zeolite minerals occur along most of the coastal area, except for very sparse development between Port George and Litchfield, silica veins are best developed east of Baxters Harbour (Fig. 1), where mutually cross-cutting relationships with zeolites are observed.

Zeolite Distribution and Classification

Based on field observations along the coastal section and a few inland exposures, a four-part classification is proposed for the occurrence of zeolites. The purpose of this classification is two-fold: first to provide a predictive means of delineating and following zeolite-rich zones for use by industry, and second to explain the occurrence of such zones by a model. Classification of the zones, summarized from field observations in Figure 3, consists (from bottom to top) of the following characteristics.

(1) The basal zone (Fig. 3a, b) contains rare disseminated amygdules, occluded and empty, and elongate vesicles (10-20 cm) occluded most often with zeolites, but rarely with a green phase (mica). Amygdules in this zone rapidly diminish vertically and, in fact, are really only concentrated in the bottom 20-30 cm of flows. In addition, there is a general trend for coarser amygdules to occur at the top of this zone, perhaps reflecting coalescence of bubbles (see below). The elongate amygdules occur at the top of the disseminated amygdule zone and are generally, but not always, inclined at 40-50°. In a single locality these elongate amygdules had a sigmoidal shape, similar to sigmoidal shear veins, and a sinistral sense of movement. The elongate amygdules have a flat, downward-facing side and an irregular, upward-facing side, and adjacent amygdules may be connected. The basal zone is overlain by up to a few metres of massive, non-vesiculated basalt.

(2) The bubble-train zone (Fig. 3c, d, e) displays extreme lateral continuity and consists of vertical (ca. 1 m), cigar-shaped pipes ca. 10-20 cm in diameter within which are zeolite-bearing amygdules. Hudgins (1960) observed these pipes infilled with agate and other silicate minerals in addition to zeolites. The amygdules, about 1-2 cm in diameter and irregular to subrounded in shape, constitute ca. 10-25 volume % of the pipe and there appears to be no obvious variation in the diameter or shape of amygdules within pipes. The maximum thickness of this zone is 4 m and the distance between pipe cores is generally uniform for a given area at 0.4 to 0.7 m. Minor amounts of flat, sheet-like zones of zeolite-bearing amygdules occur within the bubble train zone. These sheets are not seen to cut the pipes, but this relationship is not well constrained given the rarity of the sheets.

(3) The upper part of the bubble-train zone coalesces into a laterally continuous zone of inter-connected vertical pipes and flat, amygdule-rich zones which is referred to as a net-textured zone (Fig. 3f). Massive basalt lies between the amygdule-rich pipes and flat zones, and is generally, but not always, void of vesicles. This zone is ca. 1-2 m thick where present.

(4) The top of the flows contains a laterally continuous, massive disseminated zone of 1-2 m thickness which consistently contains the highest amount of amygdules, locally 25-30% (Fig. 3g, h). Zeolite-bearing amygdules are both uniformly disseminated and also aligned along flat, planar features or sheets. The amygdules in this zone are generally <1-2 cm long, but some are 10-20 cm.

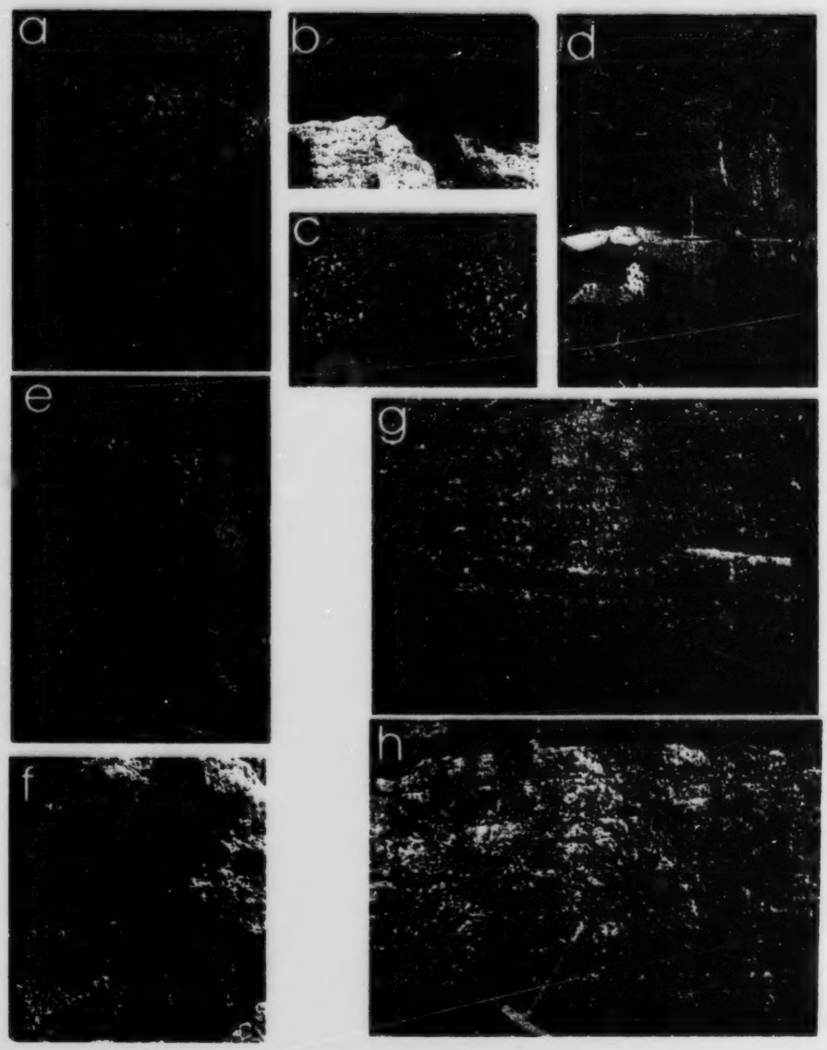

Figure 3. Field photographs of amygdules infilled with zeolites in North Mountain Basalt. (a) Two basalt flows with lower flow dark from red, hematitic alteration and also containing ca. 10% zeolites. The bottom of the overlying flow is characterized by two types of amygdules: (1) elongate, cigar-shaped amygdules that are uniformly inclined at 45-50° and occur ca. 20 cm from the bottom of the flow, and (2) small, equant amygdules that are most abundant at the base of the flow and quickly diminish upwards. In this particular occurrence only about 50% of the vesicles are infilled with zeolite. (b) Close-up of the base of a basalt flow showing in detail the shape of the elongate amygdules that characterize the basal zone. Note that the similar inclination of the amygdules, their concentration within one zone, and their uniform spacing and length. (c) Plane view of bubble-train zone showing the spherical shape of the pipes as defined by the area of amygdules. Note the absence of similar size vesicles or amygdules in the surrounding massive basalt. (d) Basalt flow of ca. 6 m thickness with very well developed bubble-train zone with pipes ca. 0.5 to 1.5 m in length. Note the massive, amygdule-free zone beneath the bubble-train zone. Note how this zone merges into the net-textured zone at the top of the photo. (e) Close-up of a bubble-train zone showing the pipe shape of the amygdule-rich areas and the very consistent length:width ratio of the pipes. (f) Net-textured zone of amygdules where the bubble-train zone has merged with a laterally extensive zone of amygdules resulting in a continuous network of amygdaloidal basalt with intervening massive, amygdule-free basalt. (g, h) Upper zone of massive disseminated amygdules where zeolites are most abundant. Note in Figure 3g that the zeolites define thin, laterally continuous sheet zones with intervening areas free of amygdules, whereas in Figure 3h areas of vesicular basalt without infill of zeolites are preserved between zeolite-rich zones.

Petrography of Zeolites and Basalts

Petrographic study of massive and amygdaloidal basalt was done with a transmitted light microscope and imaging facilities attached to the electron microprobe at Dalhousie University (Fig. 4). In transmitted light, fresh basalt specimens reveal euhedral clinopyroxene and plagioclase as isolated crystals and part of glomeroclasts, equant to skeletal Fe-Ti oxides and a dark brown mesostasis, considered to be late-stage glass that is variably crystallized. Examination of the mesostasis material in reflected light indicates an abundance of fine-grained skeletal oxide phases with textures identical to those described by Philpotts (1978, 1979, 1982) as representing crystallized Fe-rich melt formed from late-stage liquid immiscibility in tholeiitic basalt. Imaging of this same mesostasis material indicates a range of textures (Fig. 4c, d, e, g) that are considered to represent crystallization of immiscible felsic and mafic liquids under a range of cooling conditions (cf. Philpotts, ibid., and references therein). Where plagioclase and pyroxene are in contact with the mesostasis material (Fig. 4c, e, f), syntaxial overgrows of markedly different composition occur.

Altered basalt, that is amygdaloidal basalt with zeolite and other phases occluding the porosity, varies considerably in the modal proportions of minerals. Minerals present, in addition to those in fresh basalt, are mainly zeolites, albite and various mica phases, K-feldspar, Fe-oxides, and alkali amphibole, as summarized in the BSE images and mineral paragenesis figures (Figs. 5 and 6). Pe-Piper (1997) also notes the presence of barite rosettes, gypsum, and Au, Cu and Ni minerals lining pores in the zeolites (Fig. 6). The fact that zeolite and mica occur as alternating layers within the amygdules indicates fluctuations in the conditions responsible for mineral deposition. A common feature noted in this study is the albitization of plagioclase with later replacement by zeolite (Fig. 5a, b, d) and then minor amounts of K-feldspar cross-cutting the albite (Fig. 5d, e). Within the matrix of basalt occurs an abundance of zeolites as a replacment of fine-grained feldspar, replacing mesostasis material or infilling very irregular-shaped vesicles (Fig. 5f). The complexity of the paragenesis is well represented by the relationship between zeolites and micas; for example, the variation in relative timing of these two phases is shown in Figures 5c, g, i and k. The complexity of the mica textures and mineralogy is illustrated in Figures 5g and h, where the fibrous nature of this mineral phase is shown. Early formation of Fe-oxide phases, pre-dating zeolite mineralization, is documented in Figure 5j. Finally, the most interesting feature of all is shown in Figure 5l where early K-feldspar rimming a vesicle is seen to be cross-cut by later alkali amphibole (riebeckite).

Geochemistry

Geochemical analyses of the basalt and amygdule mineralogy were done at Dalhousie University using a JEOL 733 Superprobe equipped with an energy dispersive system. Operating conditions were 15 kV accelerating voltage, 15 nA beam current, 1-10 μm beam diameter and a 40 second counting time for point analysis. In addition, rastering analyses were done in order to obtain chemical analysis of basalt and the intergranular matrix; in such cases the areas rastered varied depending on the situation.

Raster Analysis of Matrix

Raster analysis on two types of basalt matrix material is summarized in the ternary plots shown in Figures 7 and 8. The areas rastered correspond to the intergranular matrix (IM) between phenocrystic phases (i.e. plagioclase and pyroxene) and a late mesostasis material (MM) which was originally glass (i.e. intergranular to the matrix phases). Note that in the chemical data are compared to whole-rock analysis of fresh North Mountain Basalt from Greenough and Dostal (1992a). With respect to the analytical results (Figs. 7 and 8), the following points are noted. (1) In general, the IM deviates markedly from the MM, with a notable enrichment of the MM in alkalis, FeO and Al_2O_3 (Fig. 7), and silica (Fig. 8b). (2) The Fe/Mg ratio remains generally uniform for all analyses, with only a few exceptions of Fe-enrichment reflecting areas strongly enriched in modal amounts of opaque phases. A similar case can be made for Fe:Ti, as shown by the proportion of normative ilmenite:magnetite (Fig. 8c). (3) The proportion of normative An:Ab (Fig. 8a) indicates two general groupings that correspond to the composition and abundance of plagioclase (see below) in the samples (i.e. calcic plagioclase (An_{50-60}) and sodic plagioclase), and also the presence of matrix zeolites. (4) Enrichment of normative Or, especially for the mesostasis material, reflects the presence of K-feldspar (sanidine ?) closely associated with quartz. These analyses reflect the petrographic occurrence of the granophyres noted previously (Fig. 4). (5) As is apparent from Figures 7 and 8, very few of the analyses from this study correspond to the area for fresh North Mountain Basalt; thus, one or more processes have resulted in modification of the primary basalt chemistry.

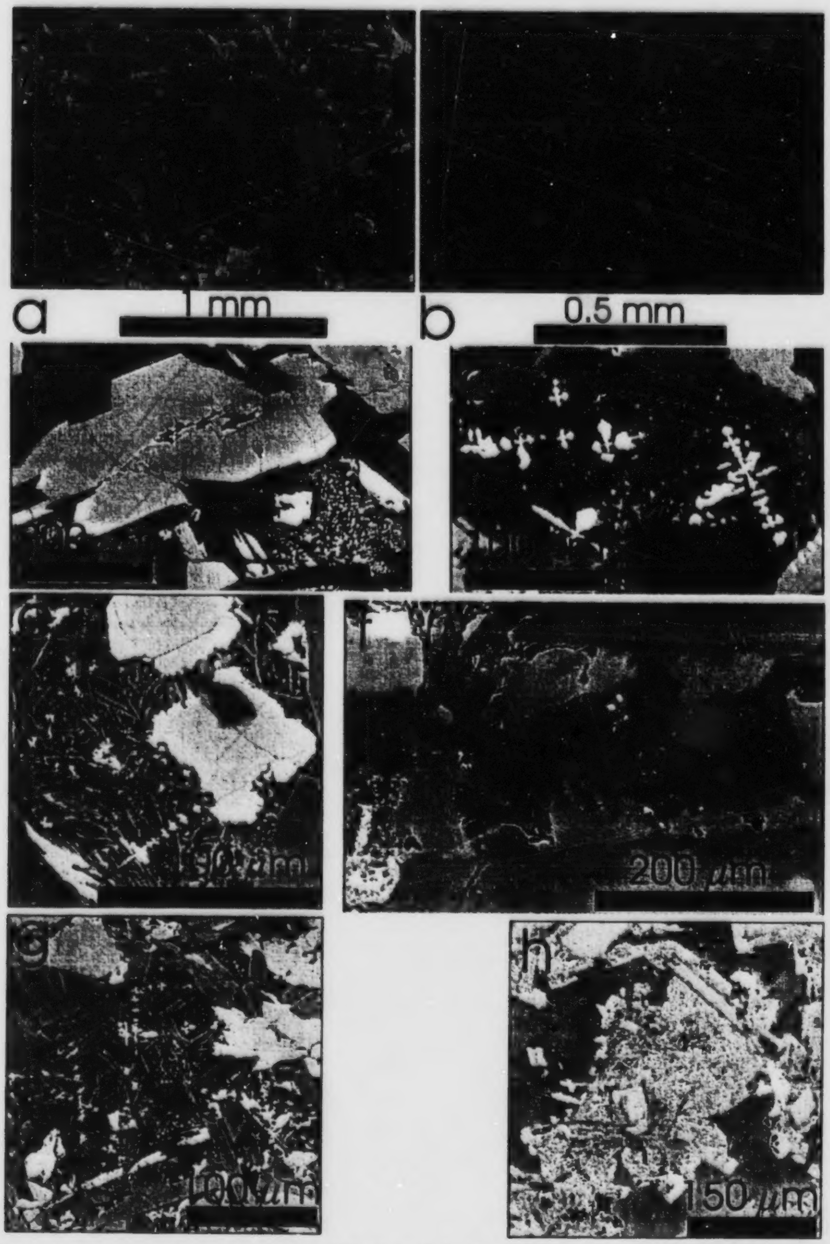

Figure 4. Petrographic features of the North Mountain Basalt, both massive and amygdaloidal. Pictures represent plane transmitted light (PTL) photos using petrographic microscope (Figs. a, b) and back-scattered electron images (BSE) taken with the electron microprobe (Figs. c to h). (a) Typical example of massive basalt with clinopyroxene and plagioclase crystals in finer grained matrix of similar mineralogy with addition of Fe-Ti oxide phase. Photo in crossed nicols. (b) Basalt with dark brown to black mesostasis material that is partially crystallized. This material represents original glass which may account for up to 25-30% of some basalt samples. Photo in PTL. (c) BSE image of clinopyroxene with an Fe-rich rim where in contact with the late-stage Fe-rich melt now full of micro-crystals of Fe-Ti oxide phase. (d) BSE image of skeletal Fe-Ti oxide phases in crystallized Fe-rich melt. (e) Late-stage Fe-rich melt with skeletal Fe-Ti oxides intergrown with spinifex textured crystallites. Note the small clinopyroxene grains with Fe-rich rims (bright border). (f) Feldspar overgrowths on large calcic plagioclase grain. Feldspar overgrowths are K-feldspar (Kf) and albitic plagioclase (Ab). (g) Similar to e. (h) Granophyre which formed from crystallization of late-stage felsic melt.

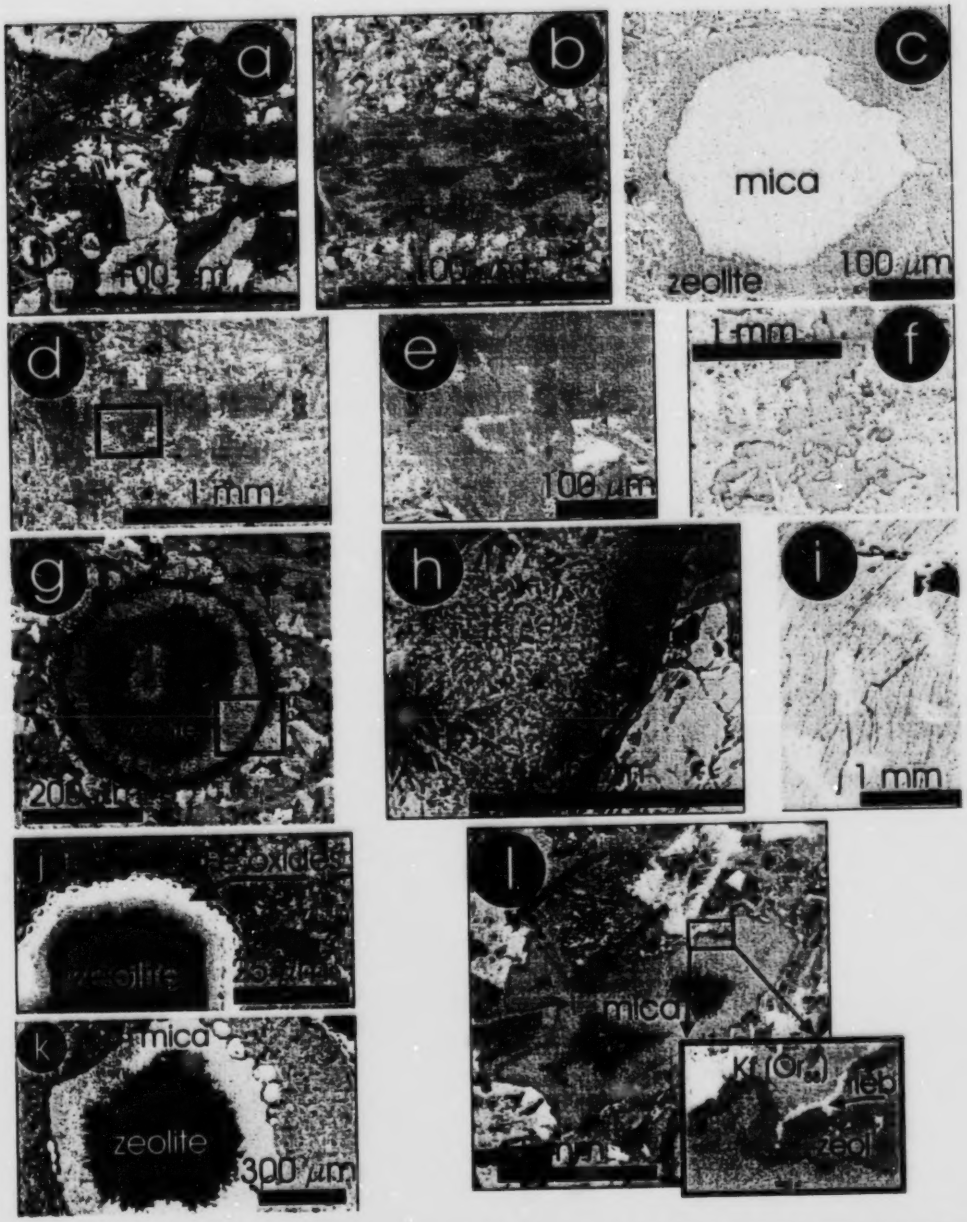

Figure 5. Back-scattered electron (BSE) images of secondary mineralogy in basalt, including amygdule phases. (a) Basalt showing albitization of the plagioclase as noted by the dark phase in the middle of the plagioclase grains. Note how fresh the pyroxene has remained. (b) Close-up of an albitized and zeolitized plagioclase with remnant patches of calcic plagioclase preserved. (c) Mica phase coring zeolite amygdule. (d, e) Zeolite pseudomorphing plagioclase and cut by later K-feldspar phase. Box in Figure 5d indicates area enlarged in Figure 5e. (f) Very irregular shaped amygdule characteristic of the finer grained amygdules in basalt. The dark rim is biotite phase and core is zeolite. (g,h) Spherical amygdule rimmed by varied mica phases and cored by zeolite. Note the box in Figure 5g is enlarged in Figure 5h and shows the delicate fibrous nature of the micas. Note how fresh the pyroxene is adjacent to the amygdule. (i) Zeolite in amygdule replaced by later mica phases. (j) Amygdule rimmed by Fe oxide phases and cored by zeolite. (k) Amygdule infilled by micas and zeolite. The bright spheres are various Fe-oxide phases. (l) Irregular shaped amygdule with rim of K-feldspar which is followed by zeolite and finally mica, but with a thin vein of alkali amphibole (riebeckite; rieb).

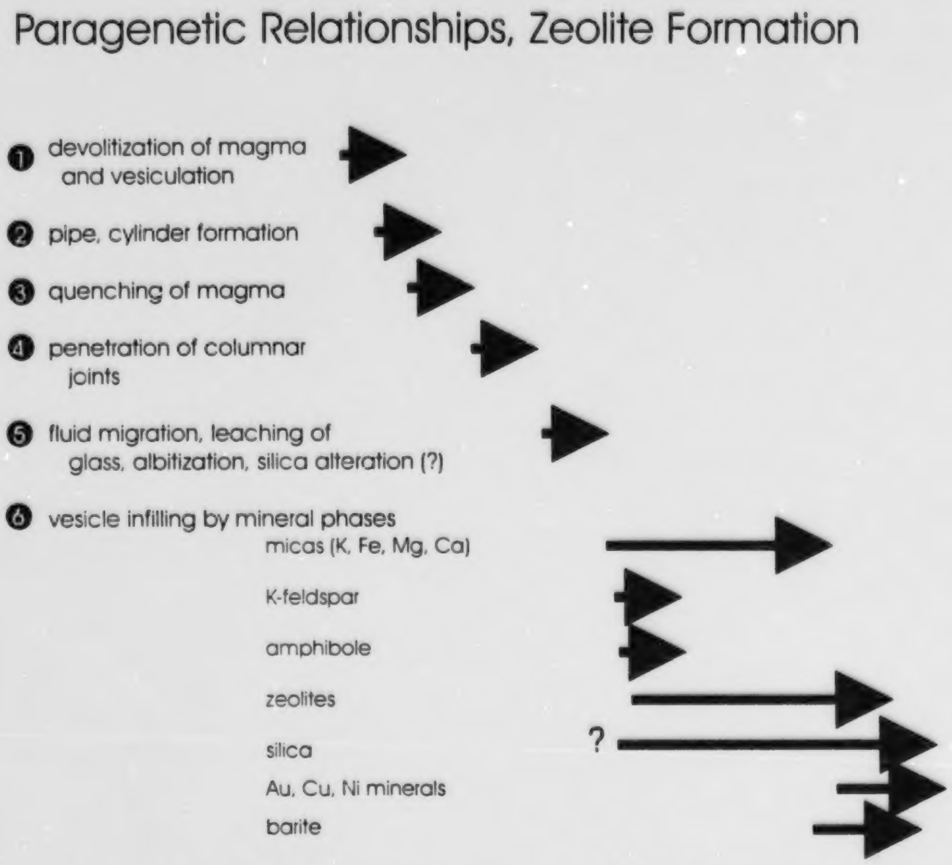
Paragenetic Relationships, Zeolite Formation
❶ devolitization of magma and vesiculation
❷ pipe, cylinder formation
❸ quenching of magma
❹ penetration of columnar joints
❺ fluid migration, leaching of glass, albitization, silica alteration (?)
❻ vesicle infilling by mineral phases
micas (K, Fe, Mg, Ca)
K-feldspar
amphibole
zeolites
silica
?
Au, Cu, Ni minerals
barite

Figure 6. Paragenesis for the North Mountain Basalt containing zeolites and other amygdule phases, including the barite and Au, Cu and Ni mineralization of Pe-Piper (1997).

Mineral Chemistry

Mineral chemistry has been obtained for both primary (pyroxene, plagioclase, oxides) and secondary (zeolite, mica, feldspar, amphibole) phases and these are discussed separately below.

Pyroxene compositions are plotted in the standard pyroxene quadralateral in Figure 9 and are compared in this diagram to results from Greenough and Dostal (1992b, c) and to the trend for the Skaergaard intrusion. Pyroxene samples correspond to the following groups. (1) Augitic pyroxene is the most common of the phenocrystic pyroxenes, and is normally zoned from an Mg-rich core to an Fe-rich rim. A single matrix pyroxene falls at the Fe-rich end of this field.
(2) Ferroaugite is restricted to narrow rims on augitic phenocrysts, as seen in back-scattered images (Fig. 4c, e). A single matrix pyroxene also falls in this field.
(3) Pigeonitic pyroxene falls in the range below subcalcic augite, which has the same broad range in terms of Fe:Mg as the augite-ferroaugite. Again, a single matrix pyroxene falls in this field. (4) Two analyses correspond to orthopyroxene of En_{40-20} composition. Analytical data from apparently altered pyroxene (i.e. red-brown material coring grains) generally overlap the field for fresh pyroxene (Fig. 9). In general, the pyroxene compositions compare well with previous mineral chemistry data for this mineral reported by Dostal and Greenough (1992b, c), although it is noted that their extreme Fe-rich compositions are for pyroxene hosted by mafic pegmatite and rhyolite within the basalt flows, and follow the crystallization trend for the Skaergaard intrusion.

Feldspar compositions, plotted in the An-Ab-Or ternary diagram in Figure 10, can be subdivided into the following compositional groups. (1) Calcic plagioclase of An_{50-70} composition occurs in phenocrystic and matrix grains. (2) Sodic plagioclase occurs as phenocrystic grains of An_{10-20} composition and matrix grains which are albitic (An_{0-10}), and include grains that are either

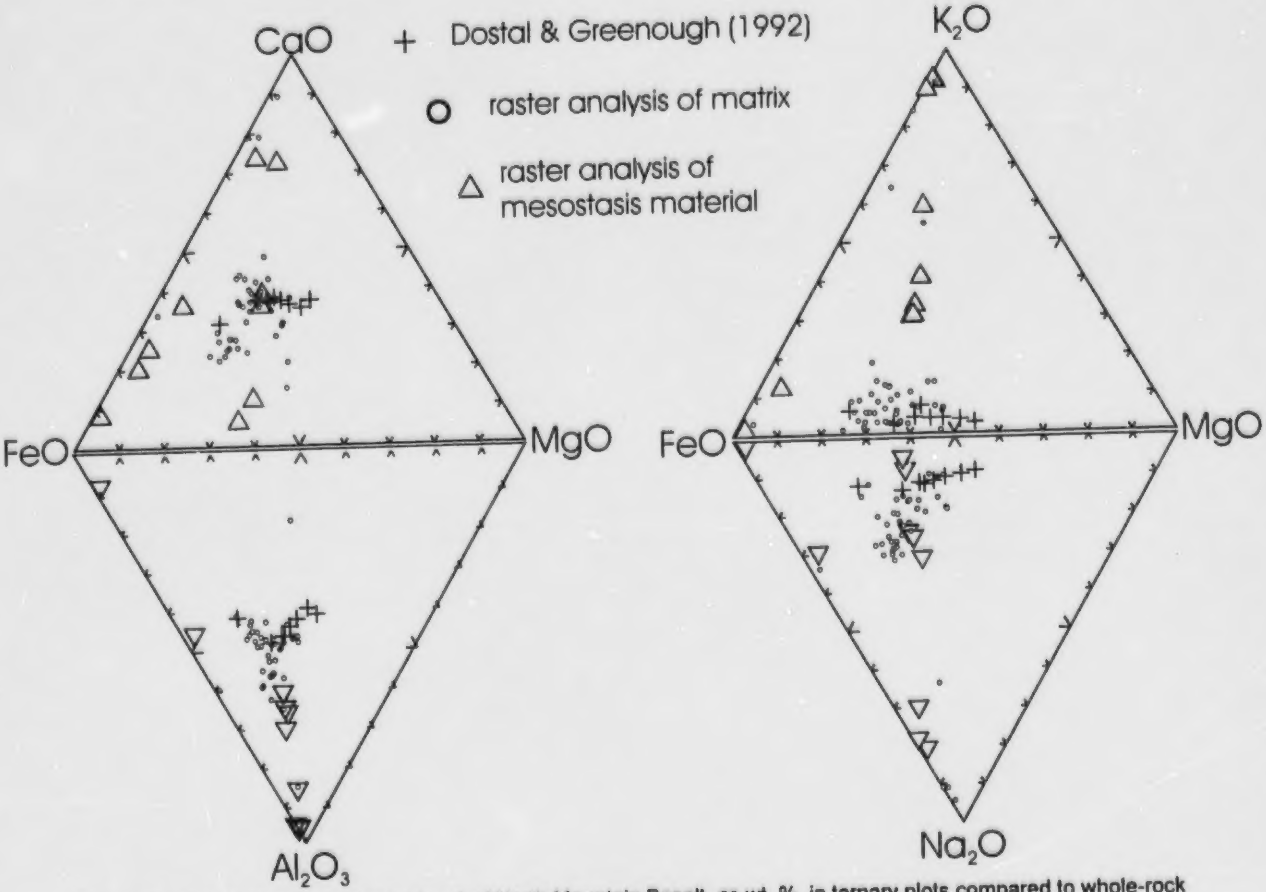

Figure 7. Chemical analysis (raster type) of North Mountain Basalt, as wt. %, in ternary plots compared to whole-rock compositions of similar material from Greenough and Dostal (1992a). The chemical data are subdivided into matrix analysis and intergranular matrix (originally glass material).

partially or totally replaced by albite. (3) Potassic feldspar of Or_{90-100} composition occurs as intergrowths within intergranular material (i.e. originally glass), lining vesicles in amygdaloidal basalt (Fig. 5l) and as micro-veinlets and blebs cross-cutting and replacing zeolitized plagioclase (Fig. 5d, e). (4) Ternary feldspar of ca. $An_{10}Ab_{50}Or_{40}$ composition occurs as intergranular material (i.e. originally glass).

The oxide phases are mixed Fe-Ti minerals whose composition appears from preliminary work to be texture dependent. The equant grains are not magnetite, as expected where immiscible Fe-rich melts form (Philpotts, 1982); instead the mixed Fe-Ti compositions approximating ilmenite chemistry reflect the reduced nature of the melts. Further work is in progress with respect to oxide mineralogy.

Zeolite chemistry, which is dominated by Si, Al, Ca, Na and K and structural water, is summarized in ternary plots of cationic proportions in Figure 11, where the results are compared to stoichiometric end-member compositions of zeolites using mineral formulae in Deer *et al.* (1962). The chemical data have been subdivided into the three types of zeolite occurrences, namely: (1) infilling vugs or amygdules, (2) replacing phenocrystic or matrix plagioclase, and (3) within the matrix. There is a clear compositional variation for the zeolites, but within a single grain the chemistry is generally uniform, that is to say that variation may occur within the scale of a thin section rather than a grain. The compositions determined correspond to a large variety of zeolite minerals and based solely on their composition it is not possible to discriminate among the various types. Instead it is necessary to integrate the chemical data with field observations and X-ray diffractometry (XRD) work, of which the latter remains to be done. Other workers (e.g. Birch, 1989; Pe-Piper, 1997) have noted similar difficulty in distinguishing among zeolites based on chemical analysis. At present, based on the Si:

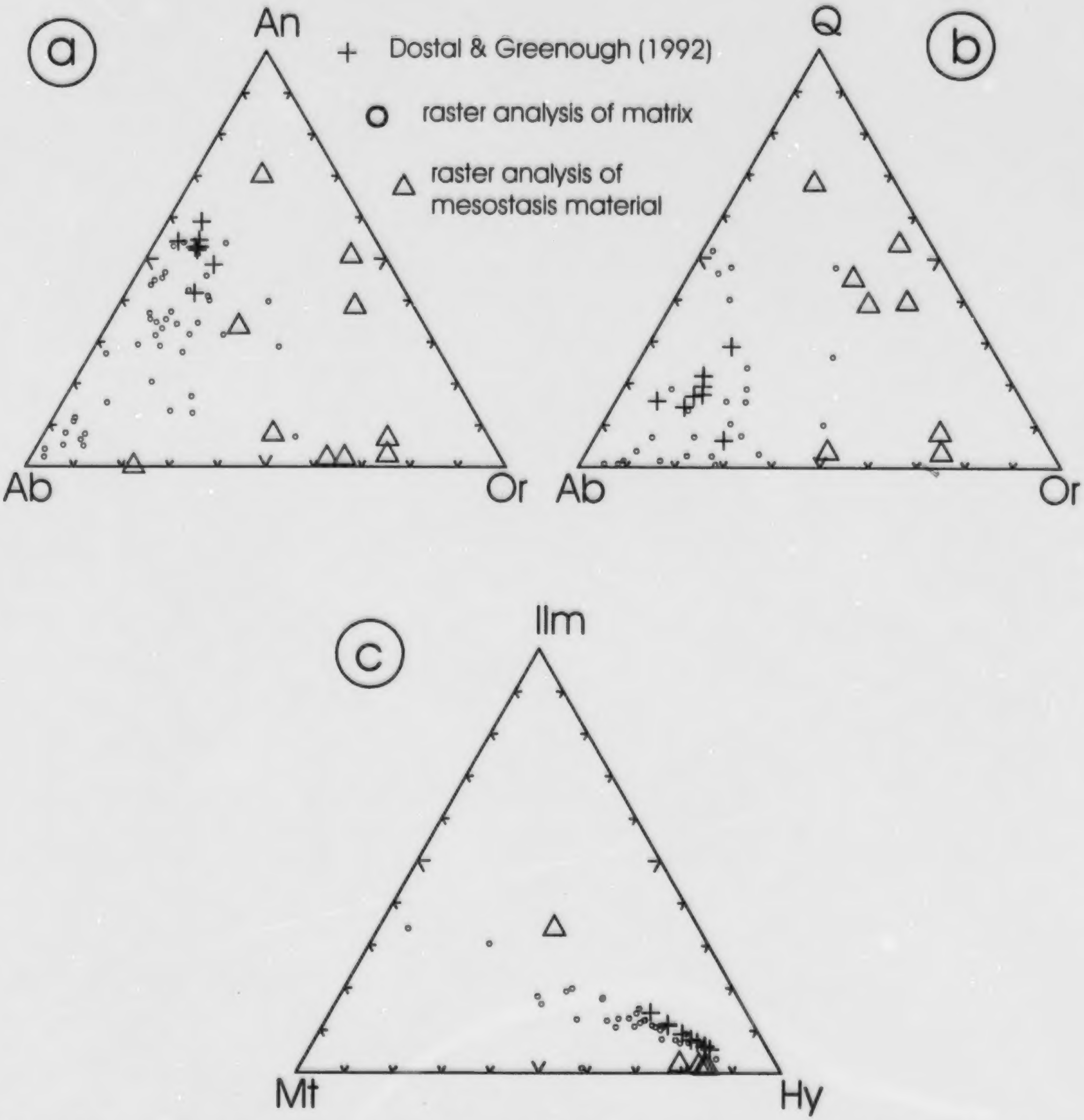

Figure 8. Chemical analysis (raster type) of North Mountain Basalt, as normative compositions, in ternary plots compared to whole-rock compositions of similar material from Greenough and Dostal (1992a). The chemical data are subdivided into matrix analysis and mesostasis material (originally glass material).

Al and Ca:Na ratios, which appear to be the best discriminators, the data are interpreted to indicate that the dominant zeolites are mainly heulandite, mordenite, chabazite and stilbite, with minor epistilbite, laumontite and thomsonite. The largest chemical variation is for zeolite infilling vugs, whereas the chemistry of zeolites replacing plagioclase and occurring in the matrix is relatively restricted.

The mica chemistry is highly variable, as summarized in various ternary and binary plots in Figure 12, and it is emphasized that these micas occur in close association. Note that in these diagrams a separation of data was arbitrarily chosen at 2 wt. % CaO in order to separate the data into what may possibly be different mica types. In the standard Al-Fe+Mg-Si ternary and Al (total) and Fe+Mg binary plots, the

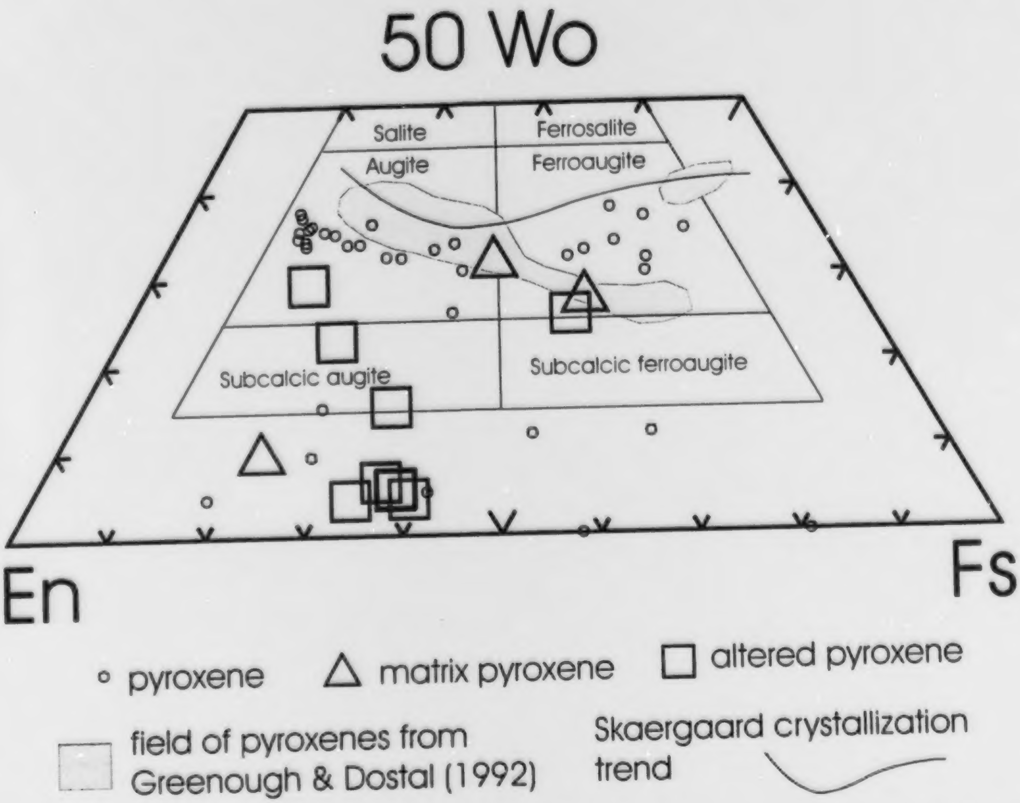

Figure 9. Pyroxene compositions plotted in the partial Ca-Mg-Fe quadralateral (50Wo-En-Fs) with pyroxene classification after Deer *et al.* (1962). The field for pyroxene compositions in the North Mountain Basalt from Greenough and Dostal (1992b,c) and Skaergaard crystallization trend are shown for comparison.

majority of data forms a continuum from muscovite to leucophyllite/celadontite. A few analyses with the most enrichment in Fe+Mg plot close to the biotite/annite Al-Fe+Mg-Si ternary. A large range in wt. % K_2O is apparent in Figure 12d, with two trends apparent: one an exchange with CaO toward margarite or clintonite/xenophyllite, and the other possibly related to chloritization, since neither substantial K or Ca is present in these micas. A positive correlation occurs for wt. % Na_2O and CaO (Fig. 12c), which together may account for 15 wt.% of the analysis. A substitution towards margarite/clintonite is suggested in Figures 12b and 12f. Clearly, additional work is required to further refine the nature of the mica phases.

A single occurrence of alkali amphibole was noted in one sample where it occurred along with K-feldspar (Fig. 5l). The chemical analysis of this mineral (Table 1) is similar to the alkali amphiboles arfvedsonite and riebeckite, as given in Deer *et al.* (1962), but the North Mountain Basalt sample is slightly higher in calcium. Using the classification scheme of Hawthorne (1981), the sample also corresponds to these two amphiboles, although the high sodic content would favour classification as arfvedsonite.

Discussion

Zeolites in the North Mountain Basalt occur in several distinct zones within individual flows that can be traced laterally for considerable distances. Formation of these zones reflects two separate phenomena: first, distribution of gas within flows and second, infiltration of a hydrothermal fluid which was responsible for precipitation of the zeolites and related phases. In the following discussion the distribution of zeolites is first addressed, followed by a discussion of their nature and origin.

Table 1. Composition and structural formulae for an amphilbole gain in amygdule, North Mountain Basalt (two analyses).

Component	Analysis 1 (%)	Analysis 2 (%)
SiO_2	49.25	49.93
TiO_2	0.06	0.09
Al_2O_3	0.58	0.16
FeO	28.21	29.90
MnO	0.45	0.47
MgO	1.53	0.60
CaO	5.28	3.19
Na_2O	10.37	11.75
K_2O	ND	ND
P_2O_5	ND	ND
BaO	ND	ND
Total	95.82	96.20
Structural formulae based on 23 oxygen (Fe as Fe^{2+})		
Si	8.000	8.112
Ti	0.007	0.011
Al	0.111	0.030
Fe	3.832	4.067
Mn	0.061	0.064
Mg	0.370	0.145
Ca	0.919	0.556
Na	3.266	3.706

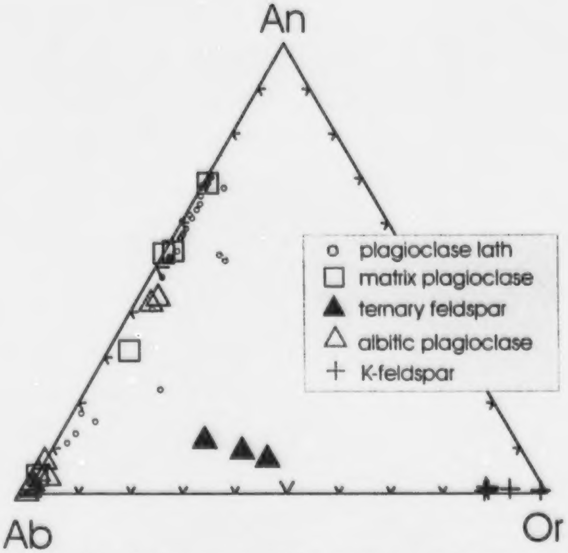

Figure 10. Feldspar compositions in An-Ab-Or ternary plot. Note that the ternary feldspar occurs in the intergranular matrix (i.e. original glass material) and K-feldspar (Or_{90-100}) as veins cutting zeolite.

Distribution of Vesicles and Mechanism of Formation

The distribution of vesicles (amygdules prior to infilling) in the North Mountain Basalt can be interpreted in the context of vesicles in basalt flows based on natural observations and combined experimental and modelling work, as summarized in Figure 13a. Vesicle distribution in the North Mountain Basalt (Fig. 3) is summarized schematically in Figure 13b and compared to distribution in other flows in Figure 13a. The comparison is striking and similar mechanisms of formation are suggested given that the host rocks are similar, being continental flood basalts of tholeiitic composition with pahoehoe features. Formation of the different zones of vesicles is summarized below, as described by Walker (1987), Goff (1996), Manga and Stone (1994) and Manga (1996), among others.

Erupting basaltic magma contains a certain initial quantity of gas formed from bubble nucleation during ascent and eruption, as represented by the uppermost frothy flow-top zone in flows (Walker, 1987). Many factors control the abundance of such bubbles, including atmospheric pressure; thus, considerable variation might be expected in the abundance of vesicles and this is what is often observed. The bottom zone, containing pipe vesicles and randomly distributed vesicles between pipes, reflects the buoyant rise of gas bubbles, with the gas either of external or internal origin. The external reservoir may be represented by water derived from an underlying reservoir overridden by the lava flows (e.g. small streams, puddles, etc.), whereas the internal reservoir is the crystallizing basaltic magma which liberates dissolved gases (H_2O, CO_2; e.g. Bottinga and Javoy, 1991). The actual formation of the pipes remains controversial (e.g. Walker, 1987; Philpotts and Lewis, 1997) and is not addressed here. The fact that most of

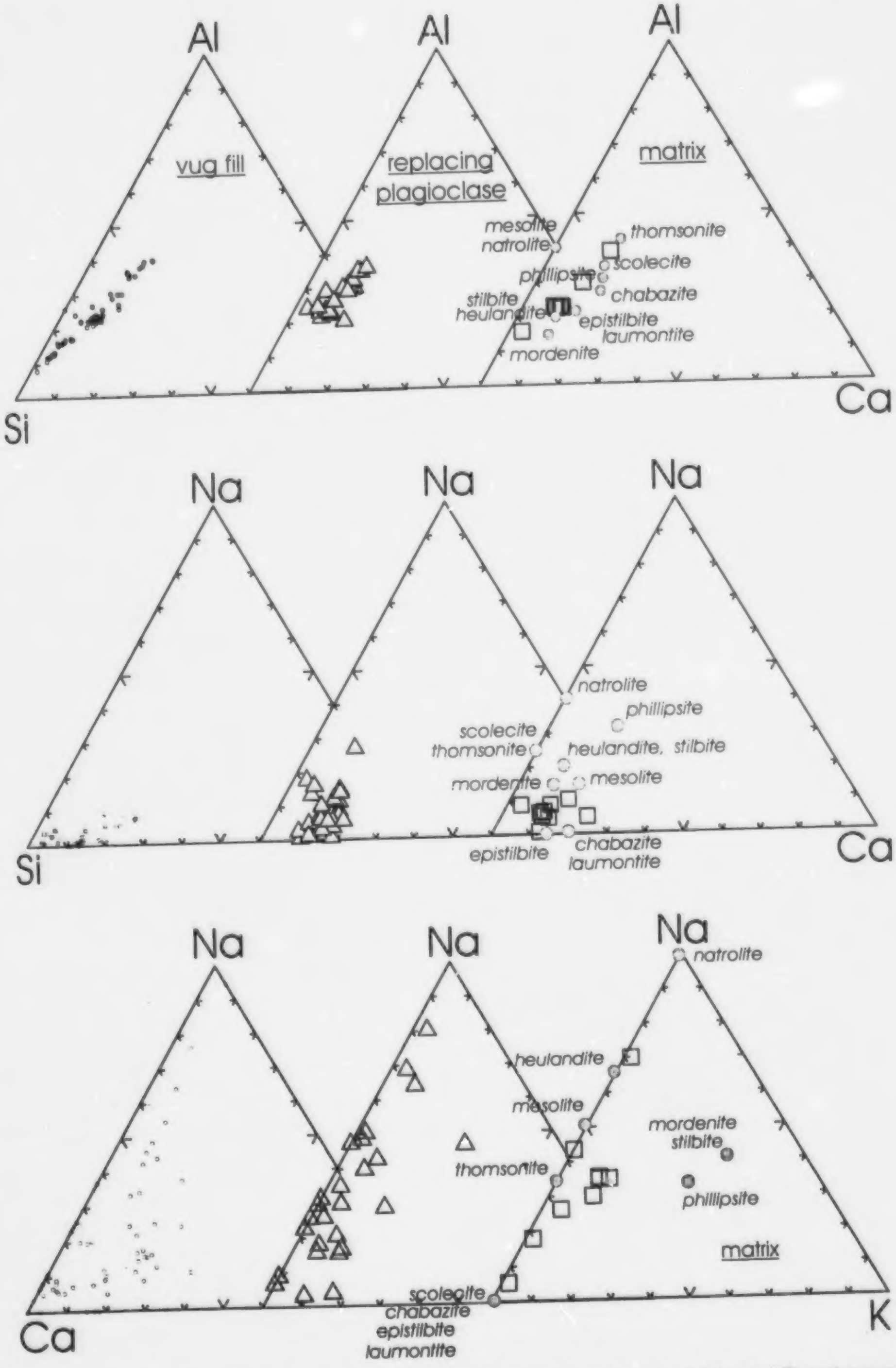

Figure 11. Ternary plots of zeolite analyses as cationic proportions plotted in terms of three different occurrences of zeolites, namely infilling vugs, replacing feldspar and within the matrix. The end member compositions for different zeolites are from Deer *et al.* (1962).

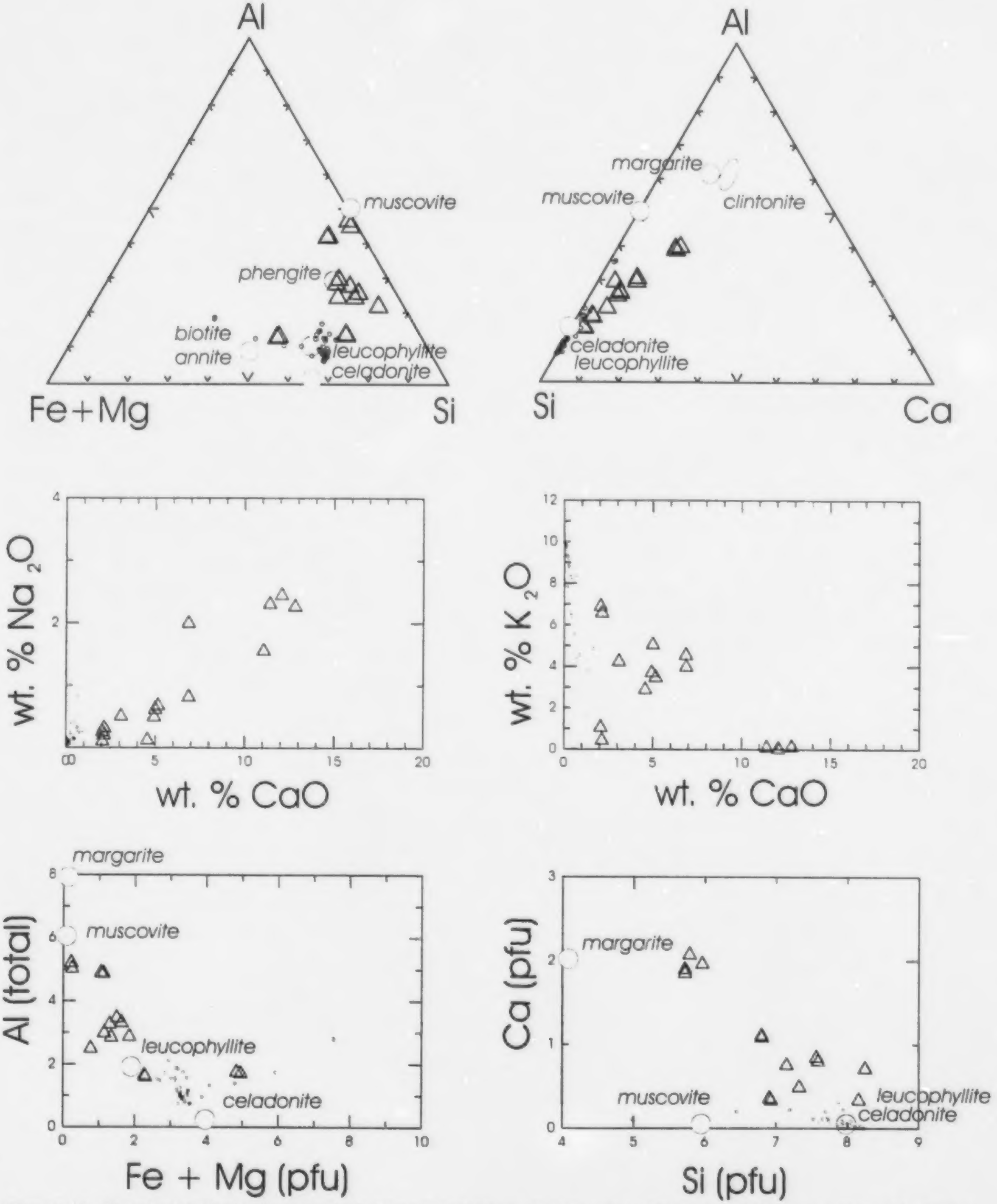

Figure 12. Chemical analysis of muscovite in ternary and binary plots based on 22 oxygen. (a) Ternary Al-Fe+Mg-Si plot (cationic proportions). (b) Ternary Al-Si-Ca plot (cationic proportions). (c) Binary element plot of wt. % Na_2O versus wt. % CaO. (d) Binary element plot of wt. % K_2O versus wt. % CaO. (e) Binary plot of Al (total) versus Fe+Mg (per formula unit). (f) Binary plot of Ca versus Si (per formula unit). End-member compositions for different micas are based on formulae in Deer *et al.* (1962).
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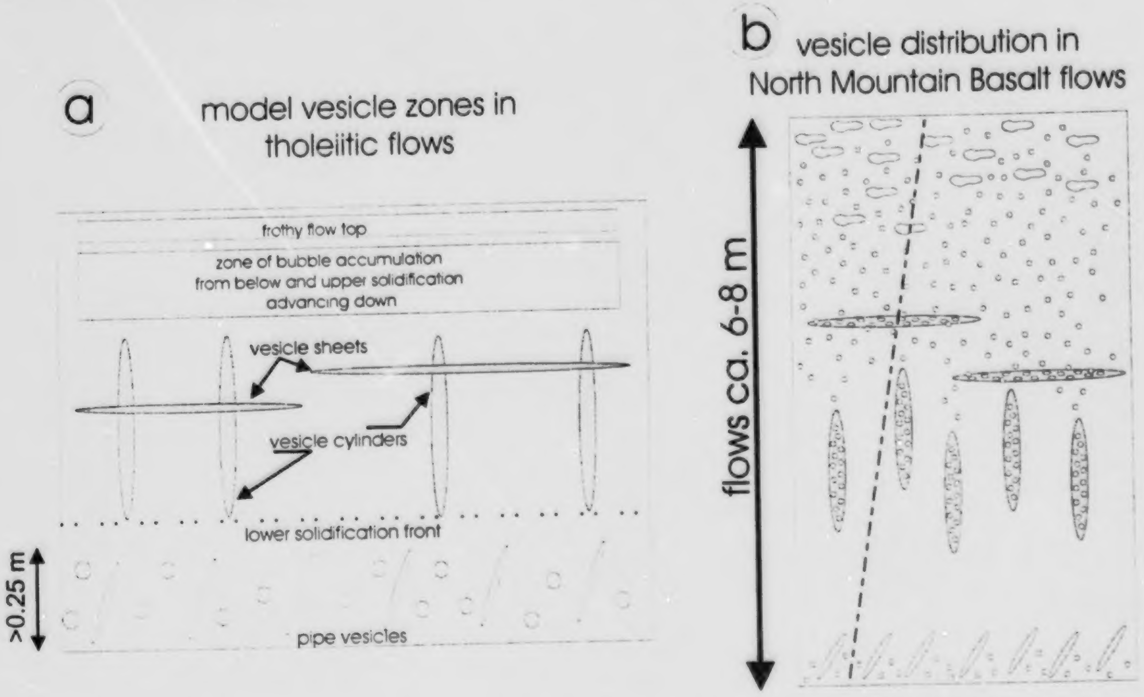
a
model vesicle zones in tholeiitic flows
frothy flow top
zone of bubble accumulation from below and upper solidification advancing down
vesicle sheets
vesicle cylinders
lower solidification front
>0.25 m
pipe vesicles
b
vesicle distribution in North Mountain Basalt flows
flows ca. 6-8 m

Figure 13. Comparison of the distribution of vesicles/amygdules in a model tholeiitic flow (McMillan *et al.*, 1987; Walker, 1987; Manga and Stone, 1994; Goff, 1996; Manga, 1996) and those observed in the flows of the North Mountain Basalt.

the pipes are inclined indicates that pipe formation preceded complete cessation of flow movement and solidification of the basalt within the bottom 1 m, which contrasts with the vertical alignment of the vesicle cylinders in the centres of flows. This observation implies a difference in timing for formation of vesicles between the two zones. Vesicle cylinders occur within the central zone and vesicle sheets merge vertically into the network zone. Their formation reflects the movement of internally generated gas into buoyant plumes and relates to the combined effects of gravitational instability and bubble coalescence and migration. Bubbles are generated due to solidification of the basaltic magma (i.e. lower solidification front) which forms a bubble-rich layer that subsequently becomes unstable in the dense basaltic liquid and begins to behave buoyantly. Although the exact model by which this mechanism operates remains uncertain (Manga and Stone, 1994; Goff, 1996), the process is generally accepted and supported by the exceptional examples preserved in places like the Columbia River basalts (McMillan *et al.*, 1987, 1989), the features of which have been successfully modelled by Manga (1996). Within the North Mountain Basalt, it should be noted that, as elsewhere (Goff, 1996), the lower bubble zone generated above the lower solidification front is not preserved within the flows, for a reason which remains unresolved.

Although not addressed or noted in other studies of vesiculated basalts, the presence of planar sheets of amygdules in the flow tops (Fig. 3g) deserves comment. This feature is locally dominant and may reflect the presence of an upper solidification front (McMillan *et al.*, 1987; Aubele *et al.*, 1988) but which is generally developed at a greater distance from the flow-top zone than observed in the case of the North Mountain Basalt. One possible explanation for the proximity of the zone to the flow top in the North Mountain Basalt is that part of the overlying basalt was eroded prior to deposition of the overlying flow, hence removing the existing evidence of the flow-top zone. Further work will be devoted to resolving this apparently unusual feature.

In summary, the different zones of vesicles in the North Mountain Basalt are similar to those documented in continental tholeiitic basalts elsewhere and their origin can be related to vesiculation of the basalts as they erupt and later crystallize. The bubbles reflect effervescence of volatiles (H_2O, CO_2) of both internal and external origin, with the latter relating to the formation of pipe vesicles in flow bottoms.

Origin of Amygdules

Infilling of the vesicles in the North Mountain Basalt required infiltration of a fluid after solidification of the basalt flows. In addition, the range of mineral phases comprising the amygdules and their compositional diversity (e.g. micas) predicate considerable variability and/or fluctuation in fluid composition. Given that the vesicles are infilled by a variety of Fe, Mg, Ca, Na, K, and Al silicates, both anhydrous and hydrous, and that there is considerable preservation of the primary silicate phases in the basalts, especially the pyroxenes, it is probable that the aforementioned elements were leached out of the mesostasis of the basalts. As noted earlier, there is considerable evidence that extensive, late-stage liquid immisicibility occurred in the North Mountain Basalt and their contrasting bulk compositions indicate a way of generating quite different fluid compositions, albeit on a local scale. In support of this scenario, it is relevant to emphasize that there is ample evidence from alteration studies of basaltic rocks, in particular ocean floor material studied in both the natural and experimental environment, to indicate that glass is readily leached by hot fluids. Thus, a model is proposed for zeolite formation in the North Mountain Basalt which first involves leaching of cations from pre-existing glass in the mesostasis of the basalt, and subsequent infilling of vesicles. The mineral zonation observed (e.g. Fig. 6) reflects both an evolving and changing fluid chemistry. In some cases there are subtle changes, as recorded by slight variation in the composition of mica or zeolite traversed with the electron microprobe, but in marked contrast to this is the abrupt change to a new mineralogy which occurs commonly.

Conditions of Amygdule Formation

The amygdule mineralogy provides some constraints on the temperature of formation, based on the known stability fields of the various minerals present. Pe-Piper (1997) notes that the presence of mordenite with labradorite suggests temperatures in excess of 250°C, whereas the occurrence of K-feldspar of Or_{90} composition overlapping zeolite deposition and locally coexisting with alkali amphibole suggests even higher temperatures of deposition (ca. 350°C). The mica phases present (rather than clay minerals such as kaolinite) also favour high temperatures, probably well in excess of 300°C (Hewitt and Wones, 1984). Further work, including fluid inclusion study and stable isotope analysis, is planned to further constrain the conditions of formation.

Summary, Conclusions and Future Work

Initial results of a study focused on zeolite distribution in basalt flows of the Jurassic North Mountain Basalt has established a four zone classification that is shown to be consistent within and between flows and is laterally continuous. Comparison to previous studies documenting the distribution of vesicles within similar quartz-normative, continental tholeiites with pahoehoe flow characteristics (e.g. Columbia River basalts) indicates a very similar vertical profile for vesicle types: a basal pipe-vesicle zone, a central cylinder- and sheet-vesicle zone, and an upper, frothy flow-top zone. The distribution of these vesicles is consistent with both experimental and theoretical studies that document formation and coalescence of bubbles within flows that result from both externally and internally derived gas components. For example, the pipe-vesicle dominated bottom zone reflects incursion of an external component early in the flow history resulting from the flow over-riding a water-rich horizon, in contrast to the central zone of cylinder- and sheet-vesicles that relate to a moving solidification front, and finally the frothy flow top which reflects the nucleation of bubbles during ascent and eruption. Preservation of this vesicle distribution reflects entrainment of gas pockets (bubbles) at the time when the flow solidified.

Subsequent infilling of the vesicles records the infiltration and circulation of an externally derived fluid, the nature of which remains to be defined. Leaching of elements from late-stage mesostasis glass, which records liquid immiscibility textures and compositions of both felsic and basic nature, provided the solutes that went into forming the amygdules. A clear paragenesis is present with the early stages dominated by Fe-, Mg- and Ca-rich potassium mica, followed by a zeolite-dominant stage. Future work will focus on constraining the thermal conditions of these stages.

The important findings of the present study may be summarized in the following points. (1) Correlation of the amygdule-rich zones with a well-documented distribution of such zones in basalt flows provides a consistent means of following these zones in three dimensions, which is of relevance to exploration and development of the zeolites. (2) The occurrence of zeolites within the non-vesiculated part of the flows is documented for the first time. This information is relevant because these matrix zeolites may account for a large percentage of the cation exchange capacity of a rock and must be considered when assessing the economic potential of zeolite-bearing rocks. In addition, since such material is not visibly enriched in zeolites, it might be overlooked in terms of its potential for economic application. This observation also accounts for the anomalously high cation exchange capacity values (CECs) obtained for whole-rock material of North Mountain Basalt (G. A. O'Reilly, personal communication, 1999).

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Petrological Studies of Aplite-Pegmatite Sheets, West Dover-Peggys Cove Region (NTS 11D/05) of the South Mountain Batholith, Nova Scotia

D. J. Kontak and J. Dostal[1]

Introduction

Previous bedrock mapping of the 370 Ma peraluminous South Mountain Batholith (SMB) has established the presence of pegmatite and aplite in various phases of the intrusion (MacDonald *et al.*, 1992). In some cases, pegmatites are known to host coarse euhedra of quartz and tourmaline (e.g. >1 cm) where late-stage pockets or vugs formed. Granitoid bodies similar to the more evolved phases of the SMB host pockets of gem-quality minerals elsewhere in the world. Previous geochemical studies of pegmatites in the eastern part of the batholith have shown that some pegmatites represent the end product of extreme crystal fractionation (Kontak and Martin, 1998), and in some cases are enriched in a variety of granophile elements (e.g. New Ross area; see Logothetis, 1984, 1985, and MacDonald, 1998, for reviews). The potential for development of pegmatites hosting pockets of gem-quality minerals is, therefore, something to be considered in parts of the SMB. In order to address this potential, a program was undertaken to assess the nature and origin of pegmatite-aplite sheets in the Peggys Cove area (Fig. 1) because of the excellent exposure and abundance of these rocks. In this paper, initial results of the past field season are presented along with some analytical data obtained for the samples collected, including whole-rock and mineral chemistry. Continuing work on the samples will include Ar-Ar dating and stable isotope analysis; these results will be presented at a future date.

Regional Geology

The study area is located on the western side of the Halifax Peninsula, an area entirely underlain by peraluminous granitic rocks of the 370 Ma South Mountain Batholith (Clarke and Chatterjee, 1988; MacDonald *et al.*, 1992). The SMB intrudes deformed rocks of the lower Paleozoic Meguma Group that were folded and metamorphosed during the ca. 395 Ma Acadian orogenic event (Kontak *et al.*, 1998; Hicks *et al.*, 1998). Although the SMB was emplaced toward the end of the Acadian Orogeny, there is evidence that it is, in part, a synkinematic batholith with regional-scale deformational features recorded, rather than a passive, post-tectonic intrusion. For example, Benn *et al.* (1997, 1999), using anisotropic magnetic susceptibility studies, have shown that the batholith retains an Acadian fabric, albeit one imposed late in the deformational history of the area. Supporting this conclusion is the work of Horne *et al.* (1988, 1992) which demonstrates that the orientation of quartz veins and aplite/pegmatite sheets reflects northwest-directed compression during emplacement of the batholith. Recent analysis of the contact aureole of the SMB indicates that the eastern part of the batholith was emplaced at pressures of 3.2 to 3.8 kbar, which equates to a depth of ca. 12-14 km (Mahoney, 1996; Raeside and Mahoney, 1996).

Recent bedrock mapping of the part of the South Mountain Batholith underlying the Halifax Peninsula indicates that the area contains a single, zoned pluton referred to as the Halifax Pluton (HP; MacDonald and Horne, 1988). Rocks constituting the HP (Fig. 1) are subdivided into: (1) a zoned sequence of biotite granodiorite to biotite monzogranite, including peraluminous cordierite and muscovite phases; and (2) muscovite-biotite leucomonzogranite. Field relationships indicate that the first sequence, which is generally coarser grained and characterized by K-feldspar megacrysts, is intruded by the latter phase, which is finer grained and porphyritic. Detailed geochemical studies have shown that the second phase rocks are more evolved and show minor lithophile element enrichment (F, Sn, W) and geochemical signatures reflecting elevated fluid:rock interaction relative to the more primitive earlier units (MacDonald and Clarke, 1992). Cutting all units of the Halifax Peninsula are steeply dipping, northwest- and northeast-trending dykes, pegmatites, and minor quartz veins (Horne *et al.*, 1988) that are generally associated with the more evolved leucomonzogranites of the HP (Fig. 1).

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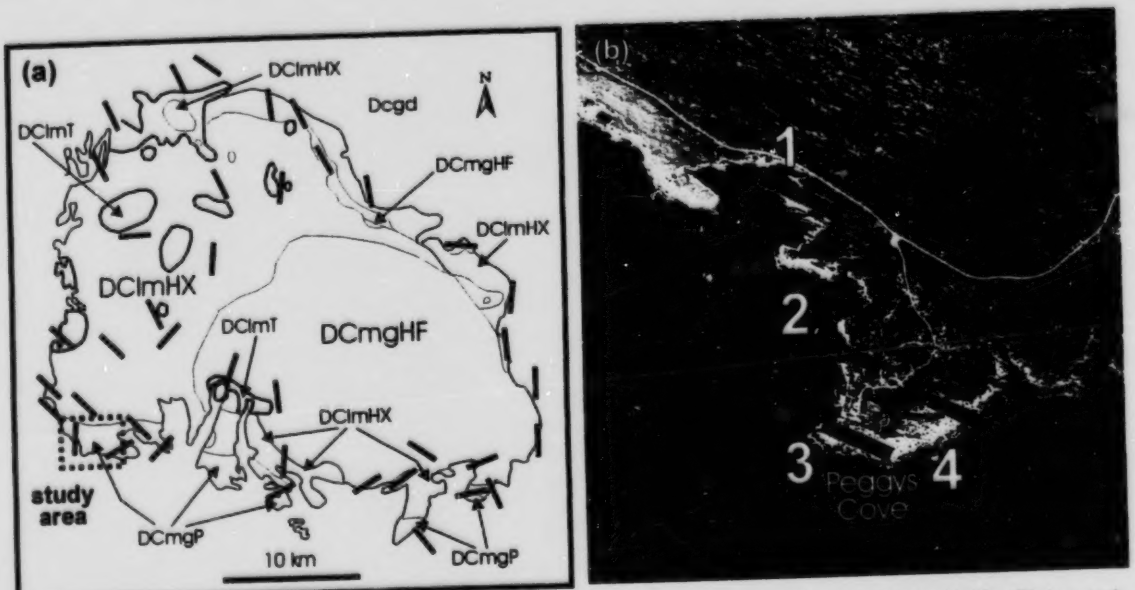
(a)
DCImHX
Dcgd
N
DCImT
DCmgHF
DCImHX
DCImHX
DCImT
DCmgHF
DCImHX
study area
DCmgP
10 km
DCmgP
(b)
1
2
3
4
Peggys Cove
Dykes or veins
DCImT Tantallon leucomonzogranite
DCImHX Halifax Peninsula leucomonzogranite
DCmgHF Harrietsfield monzogranite
DCmgP Peggys Cove monzogranite
Dcgd Granodiorite

Figure 1. (a) General geology of the Halifax Pluton and location of the study area (after MacDonald and Horne, 1988). Note the orientations of pegmatites, dykes and quartz veins. (b) Aerial photo of Peggys Cove showing the trend of aplite-pegmatite sheets and locations of areas discussed in the text. (1) Exposure of magmatic layering; (2) coarse pegmatite surrounding melanocratic xenoliths; (3) aplite sheets draping the rolling outcrops of granite near the lighthouse; (4) largest of the aplite-pegmatite sheets with excellent internal layering.

Geology of the Peggys Cove Area

Biotite Monzogranite

Within the Peggys Cove area (Fig. 1), the predominant granitic phase is a medium- to coarse-grained, K-feldspar megacrystic, biotite-muscovite monzogranite (Fig. 2), which hosts variable amounts of pegmatite and aplite defining sheeted structures. The general composition of the host granitoid is 30-35% quartz, 20-30% plagioclase, 25-40 % K-feldspar, 10-20% biotite and 2-4% muscovite. Variations in the texture and modal mineral percentages of the host granite occur on various scales, the most notable being the size and abundance of K-feldspar megacrysts, overall grain size, and percentage of biotite. In one locality, layering of biotite is exceptionally well developed and defines a magmatic foliation (locality 1 in Fig. 1b, Fig. 2a) similar to that described from Chebucto Head by Smith (1979) and, more recently, Clarke and Clarke (1998). Other notable features of the granite include: (1) an abundance of melanocratic xenoliths of various shapes and sizes (to ca. 1-2 m; Fig. 2c), which appear to resemble metasedimentary rocks, in some cases similar to the Meguma Group, but locally may represent enclaves of igneous origin as well; and (2) local ovoid zones of coarse quartz-feldspar pegmatite enveloping numerous small, corroded melanocratic xenoliths (Fig. 2d). These features were best observed near sites where magmatic layering was noted (locality 2 in Fig. 1b).

The granite is devoid of an obvious structural fabric, but is cut by numerous steeply dipping joints of generally north-south and east-west orientation. Joint measurements were made on outcrops covering the entire study area and detailed examination of the data in terms of several domains revealed no differences; hence, the data are presented collectively in stereoplots (Fig. 3). These joints have a conjugate orientation, as noted by Horne *et al.* (1988, 1992), but do not quite match the general orientations noted by these workers. Horne *et al.* (1992) relate joint formation to regional stress during emplacement of the SMB. Where the highest frequency of joints occurs, there is an appearance of comminution of the granite and this may indicate brittle deformation. No offsets were noted along any of the fracture surfaces.

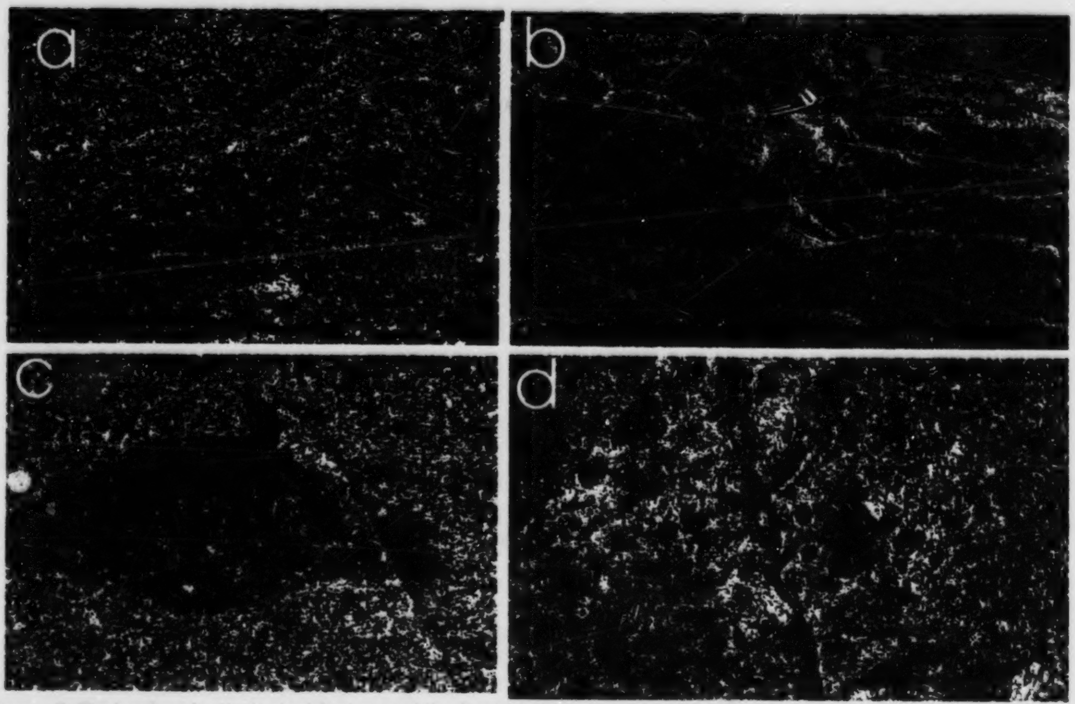

Figure 2. Textural and petrological features of the host biotite monzogranite at Peggys Cove. (a) Typical K-feldspar megacrystic granite. (b) Excellent development of magmatic layering in the granite (locality 1 in Fig. 1). (c) Melanocratic xenolith in the granite. (d) Abundant, small melanocratic xenoliths that are enveloped by coarse K-feldspar rich pegmatite.

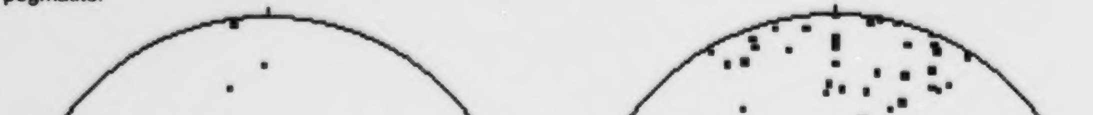

Figure 3. Stereoplots of structural data from Peggys Cove area for aplite sheets and joints in the host granite.

General Features of Aplite-Pegmatite Sheets

Aplite-pegmatite sheets display the following modes of occurrence. (1) Large, thin (1-20 cm) sheets occur draping the undulating exposed surfaces of the host monzogranite, well exposed in outcrop immediately south of the lighthouse at Peggys Cove (Fig. 4a). The sheets are dominated by fine-grained aplite, but laterally give way to mixed aplite-pegmatite up to 1-2 m in thickness and in such cases are intricately zoned (Figs. 4, 5). Dykes of fine-grained aplite are considered to be part of this group. (2) Zoned sheets 1-2 m thick occur with a bottom of fine-grained aplite and an upper half of coarse pegmatite that may locally consist of a monomineralic graphitic K-feldspar zone (Fig. 5c, d). In the latter case, the K-feldspar crystals are up to 10-20 cm long and are oriented perpendicular to the aplite-monzogranite contact (Fig. 5c, e). Commonly, granophyre surrounds the K-feldspar inwards from the contact. (3) Intricately layered or banded aplite-pegmatite-leucogranite sheets occur in thicknesses up to 3 m, with the best of these exposed several hundred metres south of the cafeteria at Peggys Cove (locality 4 in Fig. 1b; Fig. 5k). At this locality a 3 m thick section consists of numerous thick (several centimetres), undulating bands of aplite-pegmatite-leucogranite that define a banding which can be traced for several tens of metres.

Within the aplite-pegmatite sheets, there is a large variation in texture, most notably with the development of coarse segregations (up to 20-50 cm) or pods containing variable mixtures of quartz, K-feldspar, tourmaline and rarely muscovite toward the centres of the sheets (Figs. 4, 5c, e). Surrounding the pods are pegmatites, which generally overlie the segregations.

Within some of the aplites, a mm- to cm-scale banding is sometimes defined and this texture is referred to as line rock (Fig. 5b). In these rocks, the texture reflects subtle changes in modal proportions of mica and other minerals. The line rock occurs in the bottom part of zoned aplite-pegmatite sheets.

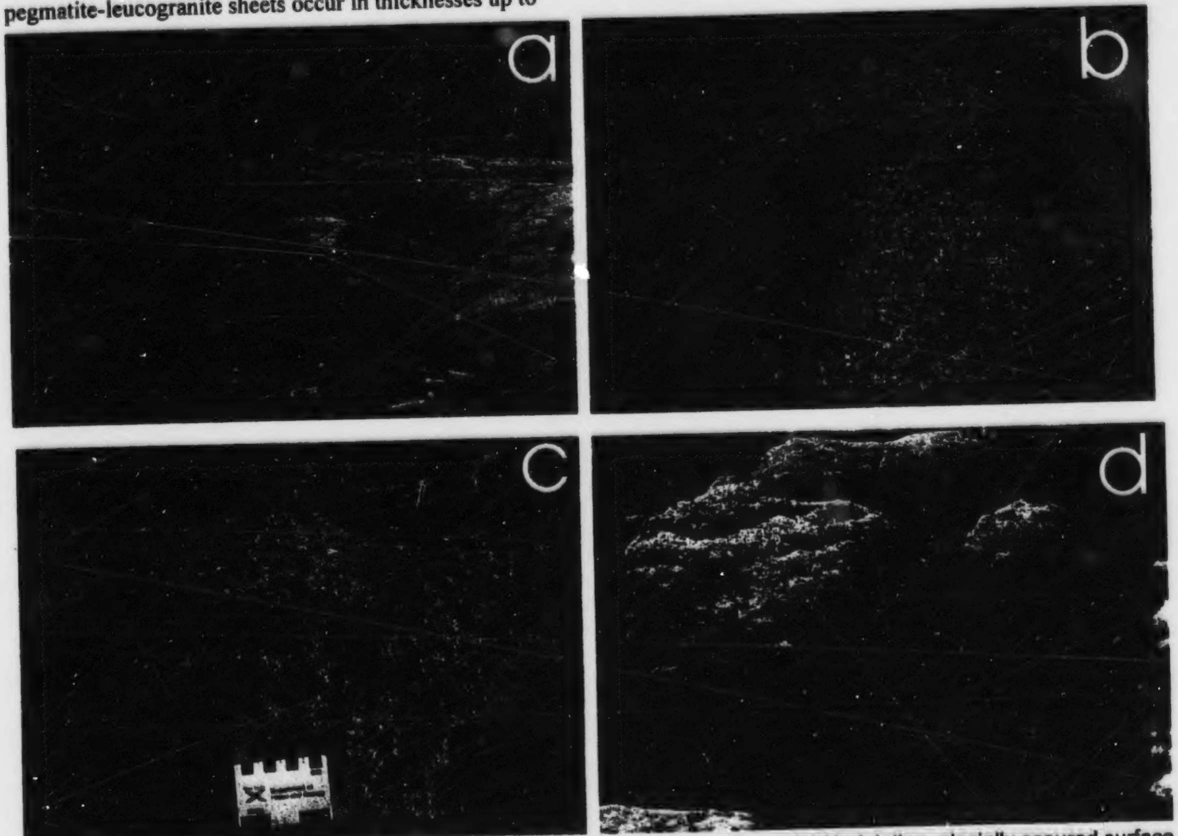

Figure 4. Zoned aplite-pegmatite sheet south of the lighthouse at Peggys Cove. (a) Undulating, glacially scoured surface of granite draped by aplite sheet. (b) Close-up of aplite sheet showing disseminated rosettes of tourmaline. (c) Coarse euhedra of tourmaline comprising rosette. (d) Development of layered aplite-pegmatite within the aplite sheet.

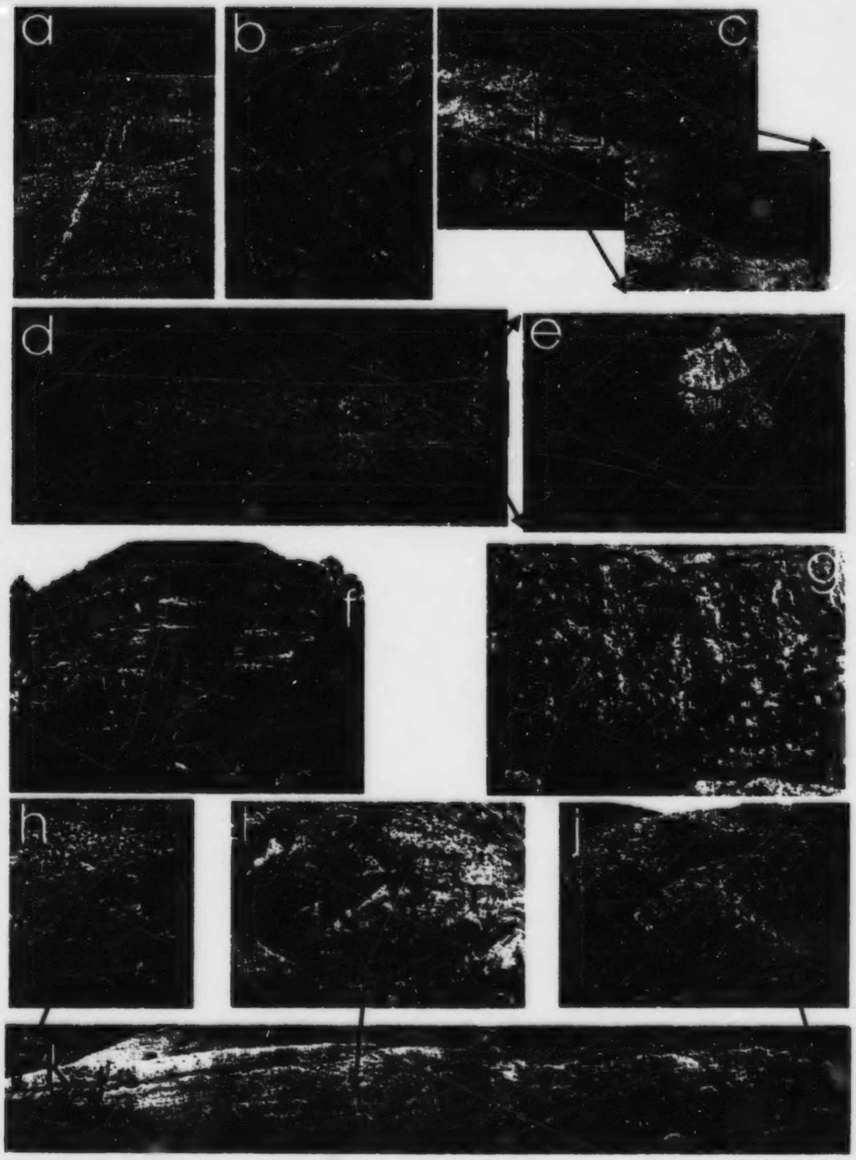

Figure 5. Examples of different features of aplite-pegmatite sheets at Peggys Cove. (a) En echelon array of aplitic dyke rocks just north of lighthouse. (b) Line rock texture in bottom of zoned aplite-pegmatite sheet. (c) Layered aplite-pegmatite sheet with bottom half consisting of fine-grained aplite and upper half consisting of coarse, K-feldspar rich pegmatite. Close-up shows the development of a quartz-tourmaline pod in the centre of the sheet. (d) Layered aplite-pegmatite sheet with bottom half consisting of fine-grained aplite and upper half coarse, K-feldspar rich pegmatite. (e) Close-up of previous photo showing the tourmaline pod developed and cleavage face of coarse feldspar crystal, one of the many that line the upper part of the tourmaline-rich pod. (f) Outcrop of granite containing numerous flat sheets of aplite-pegmatite showing mutual cross-cutting relationships. Note that the sheets are arranged as shear veins in some cases, and have tapered termination. (g) Tourmaline fibres growing on the upper surface of a pegmatite-aplite sheet. Orientations and step-like features of the tourmaline fibres indicate movement towards the northeast. (h, i, j, k) Large layered aplite-pegmatite sheet (locality 4 in Fig. 1) with fantastic example of internal organization and repetitive layering of aplite, leucogranite and coarse K-feldspar rich pegmatite in aplite sheet (ca. 3 m thick). The upper contact is marked by a zone dominated by oriented, coarse K-feldspar crystals (h), whereas the central zone is characterized by layered aplite-leucogranite-pegmatite (i).

Tourmaline occurs in the following textures within the aplite-pegmatite sheets: (a) coarse rosettes of euhedral tourmaline, disseminated within aplite sheets, that grade laterally into pegmatite-aplite sheets (Fig. 4c); (b) aligned along the contact between coarse leucogranite and fine-grained aplite within zoned sheets which extend for several tens of metres; (c) coring aplite sheets that have a thin (1-2 cm) quartz-rich centre where tourmaline euhedra occur; and (d) late-stage segregations or pods within zoned pegmatites, either intergrown with quartz (Fig. 5c) or as coarse monomineralic areas within late-stage parts of pegmatites (Fig. 5e). These tourmaline pods may be 10-30 cm wide by 10-15 cm high and contain the largest concentration of tourmaline.

A feature common to evolved pegmatites elsewhere (e.g. Tanco pegmatite, Manitoba) but which has not been observed at Peggys Cove is the absence of any apparent alteration halo about the pegmatites. As noted by London (1992), it is very common to find evidence of infiltration of the volatile component of pegmatites in the surrounding wall rock, such as the development of secondary, B-bearing minerals.

Structural Features of Aplite-Pegmatite Sheets

Aplite-pegmatite sheets generally define planar features and the following observations are considered relevant to their origin. (1) Multiple sheets may be present and they are often arranged en echelon. Cross-cutting relationships among sheets occur and these commonly have a conjugate relationship with inter-limb angles of ca. 60-70° (Fig. 5f). (2) Terminations are tapered or wedge shaped, as in shear veins. (3) Contacts with the surrounding granitic rock are welded rather than sheared or faulted. (4) Coarse crystals, generally K-feldspar but also quartz, in the marginal zones are commonly oriented perpendicular to contacts, similar to comb textures in veins. Thus, movement either during or after emplacement and crystallization is unlikely. (5) The sheets are generally flat-lying with the majority dipping gently to the south as summarized in the stereoplots in Figure 3. These orientations contrast with the orientations of joints in the host monzogranite (Fig. 3) and depart markedly from the orientations of dykes and veins in the SMB (Horne *et al.*, 1992), which are prominently northwest-trending and steeply dipping. However, the results of Horne *et al.* (1992) do show a minimal amount of data (<2% of area) clustered in the centre of their stereoplot for dykes, hence a small number of flat-lying dykes are present in the SMB, albeit fewer than are apparent at Peggys Cove. The significance of these differences is discussed later.

In a single locality, tourmaline fibers lined the upper contact of a pegmatite sheet and indicated a northeast sense of movement (Fig. 5g).

Petrographic Features of Pegmatite and Aplite

Examination of both pegmatite and aplite samples from representative areas indicates similar features for the major silicate phases: quartz, albitic feldspar, K-feldspar and muscovite. Pegmatites are characterized by the following features: (1) well-defined graphic texture, generally developed with K-feldspar, but also plagioclase. Within the scale of a thin section, several different patterns and grain sizes occur; (2) rare myrmekitic texture that is always close to areas with graphic texture; (3) comb texture at aplite-pegmatite contacts with quartz rods growing perpendicular to the contact zone; (4) late subhedral to anhedral zoned tourmaline; (5) minor pinitized cordierite (?), although in one sample this phase was abundant (ca. 5%); and (6) variably perthitic K-feldspar with remnant film type replaced by flame and bead types. In addition, the degree of mottled texture, indicative of strain, and amount of grid twinning range from rare to abundant.

In pegmatite there is a consistent paragenesis of early albitic plagioclase, plus or minus quartz, followed by quartz and K-feldspar, often with a graphic intergrowth. Muscovite and tourmaline, when present, are late in the paragenesis. Re-equilibration of the phases is indicated by development of perthitic textures in K-feldspar, strained K-feldspar with grid twinning, replacement of plagioclase by K-feldspar and development of irregular grain boundaries, and turbidity within the feldspars. Quartz is variably strained, but the timing of this feature is not constrained.

Aplite and coarser leucogranite sheets are dominated by quartz, K-feldspar and albitic plagioclase, with lesser amounts of muscovite and rare cordierite. Hypidiomorphic granular texture dominates, but extensive re-equilibration has transformed some samples into xenomorphic-textured aplite via processes described by Pollard and Taylor (1988). Where miarolitic cavities are present, they are infilled with the same minerals as the host rock. The K-feldspar contains film, flame and beaded perthite textures, and mottled textures occur along with grid twinning, especially in smaller intergranular grains. Muscovite is highly variable in abundance, from nearly absent to generally 3-5%, but where aplite-pegmatite contacts are observed up to 10-15% muscovite occurs and the grains tend to be coarser.

Chemical Analysis

Samples of whole rock and minerals have been analyzed in order to determine their petrogenesis and implications for pegmatite formation.

Analytical Techniques

Samples for whole-rock analysis were pulverized to -200 mesh at the Minerals Engineering Centre of the DalTech Campus, Halifax, and analyzed for major and trace element contents at St. Mary's University, Halifax, by X-ray fluorescence spectrometry. Mineral analysis was done in both polished thin sections and also as grain mounts, adhered to double-sided carbon tape, using a JEOL 733 Superprobe at Dalhousie University, Halifax, with the following operating conditions: 1-3 μm beam but defocused to 10 μm for feldspars, 10 nA beam current, and 15 kV accelerating voltage.

Whole-rock Data

Twelve samples of aplite and pegmatite were analyzed for major and trace elements (Table 1). This group of samples can be subdivided into the following:(1) aplite from the margin (PCG-12, 16K, 17A) and interior (PCG-16B) of sheets; (2) isolated aplite (PCG-3A); (3) coarse leucogranite-aplite (PCG-16D, 16I); (4) muscovite-tourmaline pods (PCG-14A, 14B); and (5) coarse K-feldspar (PCG-15C, 16F, 16H). The following points are noted with respect to the major element chemistry: (1) all aplite and leucogranite samples are silica rich with 74-78 wt. % SiO_2, have uniform alumina contents with 13 wt. % Al_2O_3, have K_2O/Na_2O >1.5 except for one sample at ca. 1, and are depleted in TiO_2, CaO, MnO, MgO; (2) the two muscovite-tourmaline pods are very similar in their chemistry; and (3) the K-feldspar samples have bulk compositions of Or_{60} Ab_{40} to Or_{70} Ab_{30}.

Normative compositions of the samples (Fig. 6) plot in distinct fields in a ternary Q-Ab-Or diagram. The aplite samples fall near the ternary minimum for water-saturated haplogranite (Tuttle and Bowen, 1958) and near the average aplite for the SMB (Ham *et al.*, 1988); however, the aplites also define a trend plotting toward the K-feldspar samples. Coarse leucogranites also plot within the area of fine-grained aplite.

The trace element chemistry of the samples is generally depleted except for the muscovite-tourmaline pods, which are enriched in most elements relative to other samples (Table 1), most notably the transition metals (V, Cr, Co, Ni), high-field strength (Zr, Nb, Ti) and lithophile and alkali earth elements (Rb, Sr, Ba, Ga). Most of this enrichment relates to the capacity of muscovite and tourmaline to sequester these elements. The three K-feldspar samples have the highest Rb contents, but these are well below what is found in evolved pegmatites in the SMB (Kontak and Martin, 1998) and highly fractionated pegmatites in general (Cerny *et al.*, 1985). The chemistry of aplite-leucogranite samples is generally similar, with uniformly low levels of most trace elements, except for Ba, Sr and Rb, which are highly variable.

In Figure 7, a plot of wt. % K_2O versus Rb, the data show a strong positive correlation with K-feldspar-rich samples most enriched in both elements. In order to evaluate the degree of fractionation of the samples, comparative data are shown for K-feldspar separates from pegmatite segregations in monzogranites of the SMB, pegmatites in the East Kemptville leucogranite, and highly evolved pegmatites associated with lithophile mineralization in the New Ross area. As seen in Figure 7, the coarse pegmatitic K-feldspar from Peggys Cove is less evolved than the three comparative sample suites plotted in Figure 7.

Mineral Chemistry

Feldspar

Feldspar phases analyzed included K- and Na-rich feldspar and varied perthites (i.e. film, flame, bleb) within the potasssic feldspar. K-feldspar was analyzed using both raster and point methods, the first to determine bulk composition and the latter to ascertain the composition of the re-equilibrated phase (i.e. post exsolution). A typical pegmatitic K-feldspar, imaged using the back-scattered electron (BSE) technique, is shown in Figure 8a and illustrates the nature of film and flame perthite and uniform bulk composition. Rastering and point analysis of K-feldspar indicate that, in general, compositions determined using these contrasting techniques are $Or_{70}Ab_{30}$ to $Or_{80}Ab_{20}$ for perthitic domains and $Or_{86}Ab_{14}$ to Or_{100} for host K-rich feldspar (Fig. 8b). In the former, results are considered good estimates of primary magmatic compositions given that areas dominated by film perthite were analyzed. Results for point analysis indicate that the potassic feldspar has variably unmixed and that only in a few cases did complete re-equilibration at subsolidus conditions occur. Compositions of albite occurring as various exsolution lamellae and isolated grains within K-feldspar range from Ab_{88} to Ab_{100} (Fig. 8c).

The P_2O_5 content of most peraluminous granites is a good monitor of fractionation and the South Mountain

Table 1. Whole-rock geochemistry of granitic samples from the Peggys Cove area, Nova Scotia.

Sample	PGC 99 3A	PGC 99 12	PGC 99 014A	PGC 99 014B	PGC 99 015C	PGC 99 16B	PGC 99 16D	PGC 99 16F	PGC 99 16H	PGC 99 16I	PGC 99 16K	PGC 99 17A
Rock	aplite	aplite	musc-tour pod	musc-tour pod	Kfeldspar	f gr aplite	coarse lcgr-aplite	Kfeldspar	Kfeldspar	coarse lcgr	marginal aplite	aplite
SiO_2	78.19	74.69	55.04	57.13	75.2	75.48	76.01	75.22	74.45	75.71	75.08	76.62
TiO_2	0.048	0.062	0.956	0.929	0.043	0.052	0.052	0.039	0.05	0.054	0.046	0.04
Al_2O_3	13.1	13.98	21.13	17.92	13.68	13.68	13.36	13.7	13.32	13.68	13	13.62
Fe_2O_3	0.55	0.32	8.68	7.55	0.39	0.36	0.65	0.28	0.47	0.69	0.58	0.37
MnO	0.022	0.006	0.238	0.386	0.007	0.002	0.015	0.003	0.005	0.02	0.021	0.004
MgO	0.03	0.04	1.7	2.11	0.02	0.03	0.1	0.01	0.03	0.09	0.08	0.05
CaO	0.48	0.38	0.15	0.14	0.3	0.28	0.31	0.14	0.15	0.62	0.52	0.39
CaO	0.48	0.38	0.15	0.14	0.3	0.28	0.31	0.14	0.15	0.62	0.52	0.39
Na_2O	3.59	3.12	0.34	0.27	3.03	3.31	2.86	2.58	2.14	4.01	3.26	2.98
K_2O	4.55	6.08	4.75	3.52	6.44	5.03	5.63	7.57	8.2	4.09	5.14	6.3
P_2O_5	0.125	0.193	0.164	0.14	0.143	0.14	0.108	0.161	0.149	0.116	0.144	0.211
LOI	0.65	0.93	7.74	9.01	0.4	1.35	0.68	0.39	0.37	0.62	0.71	0.7
	101.815	100.181	101.038	99.245	99.953	99.994	100.085	100.233	99.484	100.32	99.101	101.675
V	0	0	132	117	0	0	0	3	0	0	0	0
Cr	8	9	97	78	7	12	15	1	5	11	13	6
Cs	0	0	26	23	0	0	0	0	0	0	0	0
Zr	22	22	189	212	4	26	22	2	3	16	16	17
Ba	0	230	672	4361	0	173	0	124	192	0	161	258
La	2	0	63	55	5	0	0	3	0	2	0	5
Ce	0	17	84	63	24	37	0	26	36	22	33	30
Nd	13	8	41	29	2	8	8	0	9	5	8	5
Ni	0	0	44	29	1	1	0	0	3	0	0	0
Cu	0	0	15	11	0	0	0	0	0	0	0	0
Zn	17	15	10	8	18	24	18	10	12	24	15	15
Ga	17	17	27	23	15	20	16	16	14	16	16	17
Rb	251	265	148	121	303	221	207	361	253	180	183	216
Sr	27	34	660	629	15	23	27	9	26	15	42	39
Y	0	0	35	34	0	0	0	0	0	0	0	0
Nb	5	5	18	17	1	7	5	1	3	5	4	3
Sn	8	8	4	4	7	8	8	7	7	8	8	8
Pb	41	54	10	11	42	114	49	47	55	42	42	57
Th	6	6	15	14	6	7	4	2	4	6	7	6
U	1	1	4	3	1	2	1	0	1	1	2	1

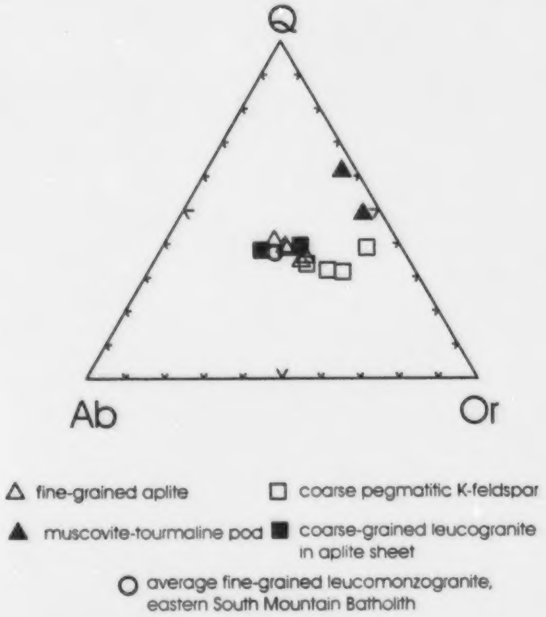

Figure 6. Ternary normative plot of quartz (Q) - albite (Ab) - orthoclase (Or) for whole-rock analysis of samples from Peggys Cove. Data are compared to the average composition of fine-grained leucomonzogranite in the South Mountain Batholith (Ham *et al.*, 1988).

Batholith is no exception. Kontak *et al.* (1996) have shown that there is a systematic increase of P_2O_5 in both K- and Na-rich feldspar toward more evolved granite compositions. Thus, the level of ≤ 0.5 wt. % P_2O_5 in pegmatitic feldspar (Fig. 9) contrasts markedly with levels of up to 1-2 wt. % P_2O_5 in pegmatitic feldspar from the SMB (Kontak *et al.*, 1996). The BaO content of feldspars collectively ranged from below detection limits (ca. 0.20 wt. %) to a maximum of ca. 0.6 wt. %, but results were very erratic both within grains and between samples.

Plagioclase feldspar in leucogranite and aplite varies from An_{12} to An_0 composition, as is typical of this mineral phase in evolved granites, including the SMB (MacDonald *et al.*, 1992).

Muscovite

Muscovite, occurring as coarse isolated grains in pegmatite and fine- to medium-grained leucocratic granite (i.e. aplite), and within cavities of leucogranite in sheeted aplite-pegmatite, generally has a uniform chemistry. Imaging (BSE) of individual grains indicates homogeneous chemistry, as confirmed by point analysis of grains. Collectively the analyses (Fig. 10) indicate that muscovite has the following chemistry: 0.6 ± 0.4 wt. % MgO, 1.4 ± 0.6 wt. % FeO, 0.6 ± 0.2 wt. % Na_2O and 0.2 to 0.5 wt. % TiO_2. There is a positive correlation between FeO and MgO, but the data define a large range in the MgO:FeO ratio (1:1 to 1:5). This variation reflects differences between samples, as the Mg:Fe ratio within a sample is generally uniform. Small muscovite grains in feldspar, interpreted to be of secondary origin, are notably depleted in FeO, MgO and TiO_2 compared to the coarser, isolated muscovite grains. Chemical features of the muscovite grains compare to those for muscovite in the SMB (Ham and Kontak, 1988) and the larger data set of mucovite compositions for granitic rocks compiled by Miller *et al.* (1981). More recently, Zane and Rizzo (1999) compiled the compositional space of muscovite in granitic rocks and from their compilation the Peggys Cove muscovites compare to those from granitic rocks in general, but contrast to compositions for evolved pegmatite and aplite. The Peggys Cove muscovite is depleted in F and Cl and neither element was detected during analysis.

Apatite

Apatite in the aplite, coarse leucogranite and pegmatite falls into two groups based on chemistry and occurrence (Fig. 11), namely: (1) grains enriched in Mn that are disseminated within aplite-leucogranite, versus (2) Mn-depleted grains that are disseminated within feldspar. The former tend to be coarser and the latter are associated with turbid areas within the feldspars, based on imaging analysis. The strong negative correlation between wt. % CaO and MnO for the apatite analysis reflects a Ca ⇌ Mn exchange mechanism. All apatite grains analyzed are depleted in both F and Cl, thus mimicking the similarly deficient nature of muscovite with respect to these volatiles.

Tourmaline

Tourmaline from pegmatite and within leucogranite is strongly zoned in terms of wt. % SiO_2, Al_2O_3, FeO, MgO and Na_2O (Fig. 12), with a strong positive correlation between SiO_2 and Al_2O_3 and Na_2O (Fig. 12a, c), and a negative correlation between MgO and FeO (Fig. 12b). From both petrographic and BSE imaging, tourmaline appears to have a broad, chemically homogeneous core and narrow, strongly zoned border which is characterized by maximum Fe enrichment. In the Mg-Al-Fe ternary plot for classification of tourmaline, the data show a large variation and generally fall close to the fields for tourmaline in metasedimentary rocks rather than evolved granites. The data correspond to the field defined by Clarke *et al.* (1989) for tourmaline from a variety of occurrences in the SMB.

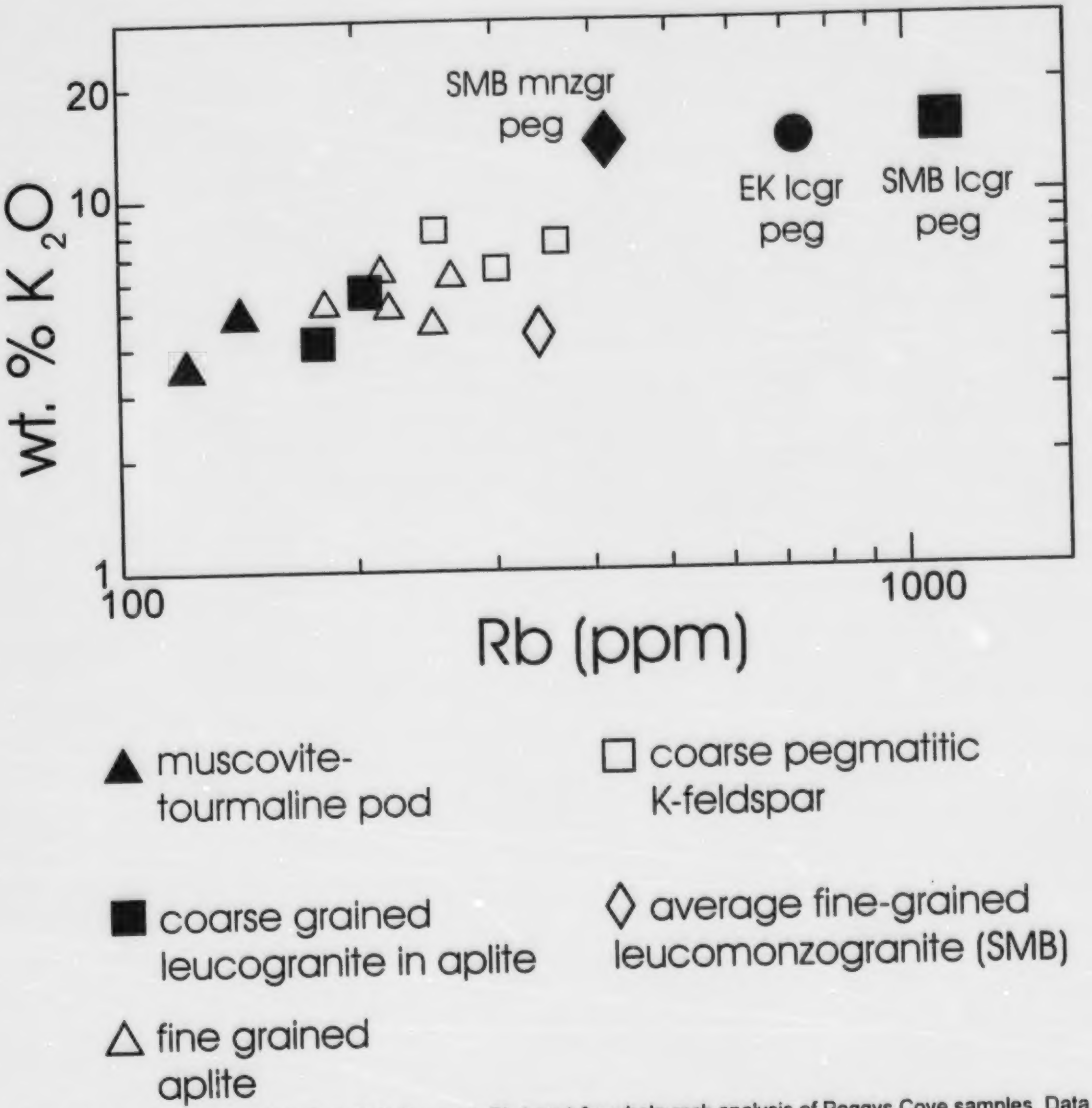

Figure 7. Binary element plot of wt. % K_2O versus Rb (ppm) for whole-rock analysis of Peggys Cove samples. Data are compared to K-feldspar samples from pegmatites of various settings in the South Mountain Batholith, namely segregations in monzogranites (SMB mnzgr), evolved pegmatites in the New Ross area (SMB lcgr peg), and segregations in the East Kemptville leucogranite (EK pcgr peg). Data are compared to the average composition of fine-grained leucomonzogranite in the South Mountain Batholith (Ham *et al.*, 1988).

Fluid Inclusions

Fluid inclusion samples have been prepared and examined petrographically, and preliminary thermometric data collected using a USGS gas-flow heating-freezing stage (see Kontak, 1998 for details). Herein, petrographic features of the inclusions are described along with initial results of thermometric measurements and decrepitate analysis.

Petrographic Observations

Four samples of pegmatite were selected for fluid inclusion study in order to constrain the chemical and physical conditions of aplite-pegmatite formation and the following observations are related to quartz-hosted inclusions. The quality of the inclusions present varies considerably and no inclusions could readily be related

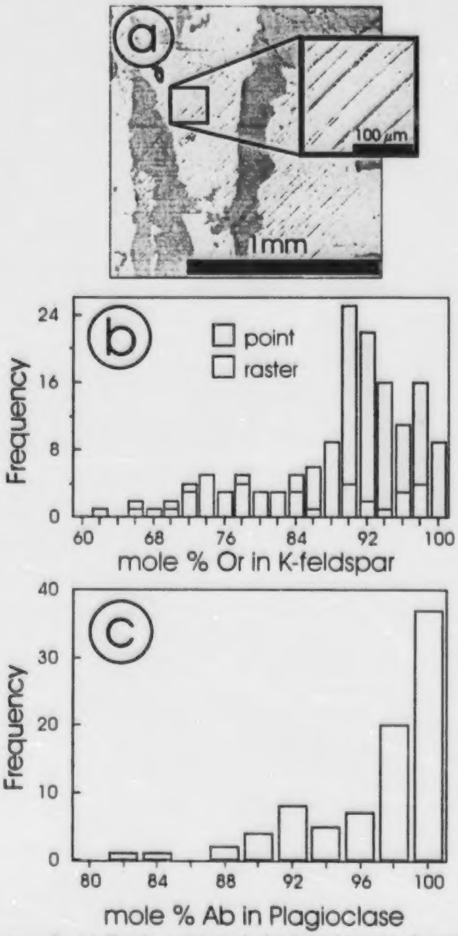

Figure 8. (a) Back-scattered electron image of perthitic alkali feldspar (light grey) intergrown with quartz (dark grey) in pegmatite sample from Peggys Cove. Note that the raster analysis of the inset area provides an estimate of the bulk composition of the alkali felspar. (b) Point and raster analysis of alkali feldspar. (c) Analysis of exsolution lamellae in perthitic feldspar.

to growth features, hence they are tentatively considered pseudosecondary and secondary (Roedder, 1984). The following four types of inclusions were recognized at room temperature (ca. 25°C). (1) Two-phase, liquid-vapor (L-V) inclusions were found with regular, equant or negative shape to irregular shape, and mostly 5-20 μm, but up to 40-60 μm. The L:V ratio of these inclusions is consistent within a population, but varies considerably among populations, thus indicating trapping of fluid over a range of temperatures. Type 1 inclusions dominate samples and occur as isolated groups (this mode of occurrence has the greatest L:V ratios) or along healed fractures and planes. In the latter case, extensive necking (e.g. Roedder, 1984)

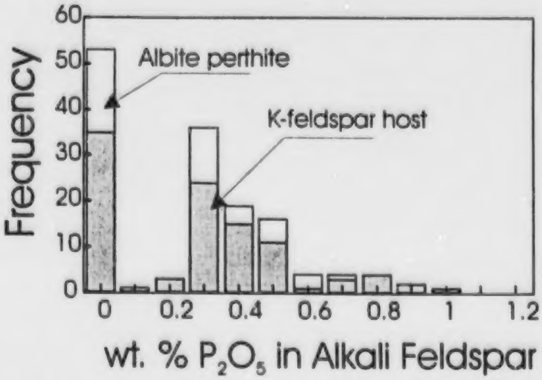

Figure 9. Histogram plots of wt. % P_2O_5 in K-feldspar (note point type analysis) and albite lamellae in perthitic feldspar in pegmatites and aplites, Peggys Cove.

characterizes such areas. (2) Three phase (L-V-halite) inclusions are rare and occur along healed fracture planes as equant to elongate inclusions of 10-20 μm. In some cases a second, unidentified solid occurs. (3) V-rich inclusions of equant or negative shape and $\leq$20 μm length occur along healed fractures. These inclusions, which are exceptionally rare, were not observed to coexist with either type 1 or 2 inclusions and there is no evidence to suggest that they owe their origin to post-entrapment processes (such as necking; Goldstein and Reynolds, 1994). (4) Multi-solid-V inclusions of irregular shape and $\leq$30-50 μm length occur with type 1 inclusions. The solids are of variable shape and birefringence and appear to be mica and feldspar and may represent accidental trapping of silicate phases related to late-stage crystallization and alteration within the pegmatite (?).

Thermometric Analysis

Thermometric data for quartz-hosted fluid inclusions are shown in Figure 13. Inclusions were homogenized to the liquid phase over a temperature range from 140° to 300°C, although a much smaller range occurs for individual fluid inclusion populations. The few halite-bearing fluid inclusions were homogenized by halite dissolution at 130° to 133°C. However, it is noted that the majority of the data fall in a much narrower interval from 160° to 200°C (Fig. 13a). Inclusion data are pressure-corrected, assuming a pressure of ca. 3 kbar at the time of pegmatite formation (e.g. Clarke and Chatterjee, 1988), to about 300° to 600°C for the appropriate salinities (see below) using the isothermal lines for ca. 25. wt. % NaCl in the H_2O-NaCl system (Bodnar and Vityk, 1994).

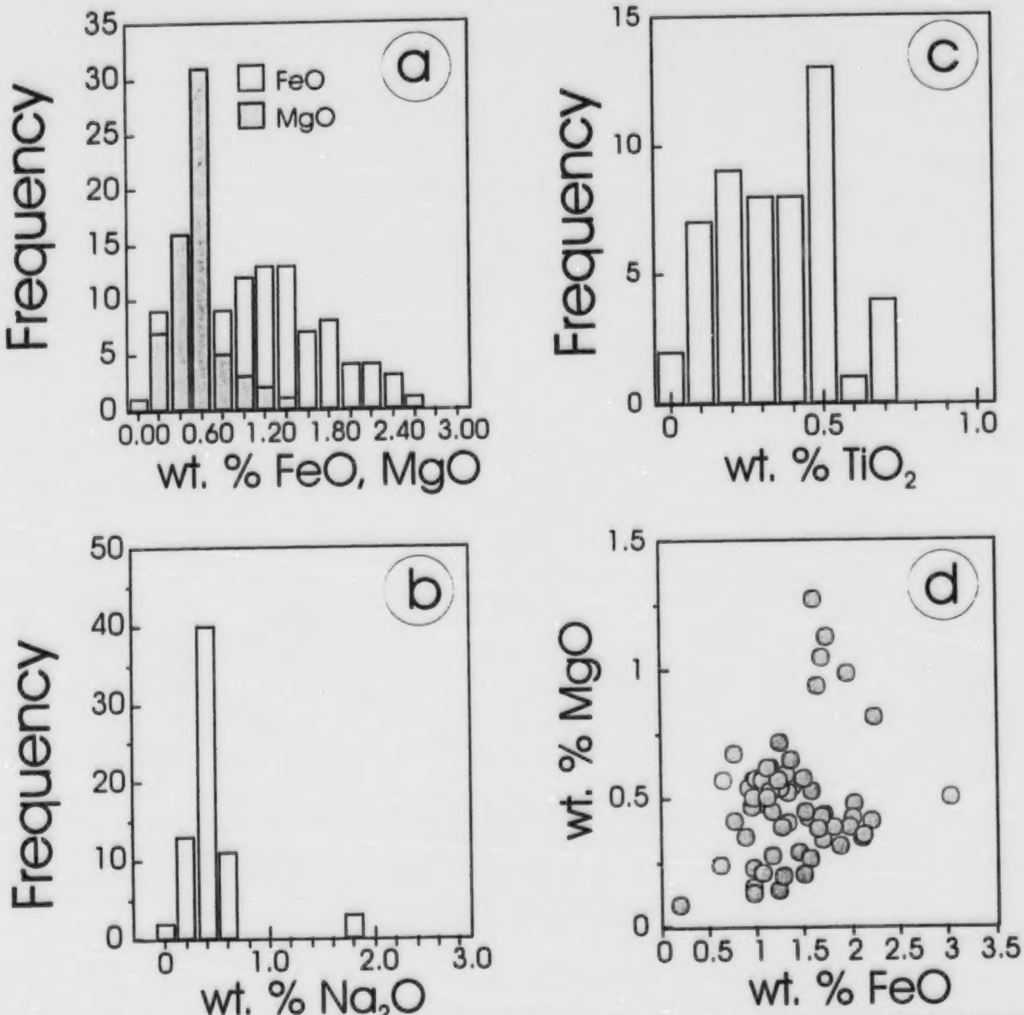

Figure 10. Chemistry (wt. %) of muscovite in pegmatites and aplites from Peggys Cove summarized in histogram plots of: (a) FeO and MgO,(b) Na_2O, (c) TiO_2 and (d) binary element plot of MgO versus FeO.

Freezing of the inclusions indicates that the fluids represent mixtures of H_2O-NaCl-$CaCl_2$, based on the low first melting temperatures of ca. -65° to -55°C and disappearance of hydrohalite in the inclusions in the temperature range of -42° to -30°C. The disappearance or last melting of ice indicates salinities (equivalent wt. %) of 4 to 30 wt. % equivalent NaCl, but most of the data fall in the range 20 to 26 wt. % equivalent NaCl (Fig. 13b). The highest salinities (30 wt. %) correspond to inclusions containing halite.

Decrepitate Analysis

Two samples of pegmatitic quartz containing the best inclusions were artificially decrepitated on the heating stage and mounds formed from the precipitates (Fig. 14) were analyzed using a combined imaging-energy dispersive system on the Dalhousie University electron microprobe. The only cations detected were K, Na and Ca, hence the data are summarized in the K-Na-Ca ternary plot of Figure 14. Results indicate that two fluid types are present, one a K-Na fluid and the other a Na-Ca fluid, and it is emphasized that there is very limited exchange of the K-Na fluid with the Ca-rich reservoir or fluid. These results are very similar to analysis of decrepitate mounds from mineralized quartz veins and pegmatites from the New Ross area of the South Mountain Batholith (Carruzzo *et al.*, in press).

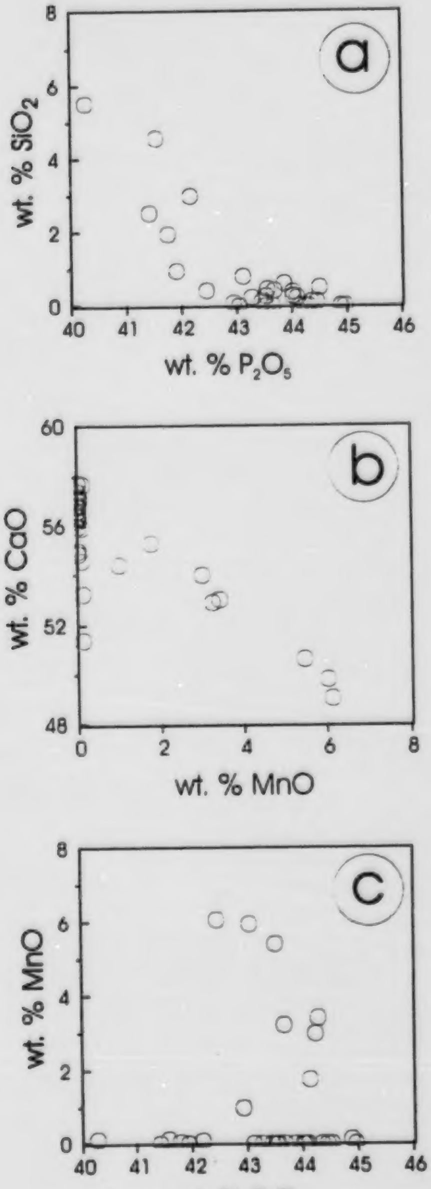

Figure 11. Binary element plots for apatite (wt. %) in pegmatites and aplites, Peggys Cove: (a) SiO_2 versus P_2O_5, (b) CaO versus MnO, and (c) MnO versus P_2O_5. Note the two groups of analysis based on the amount of MnO, as discussed in the text.

Discussion and Conclusions

The occurrence and nature of abundant pegmatite-aplite sheets at Peggys Cove are not unusual in terms of layered pegmatites in general; however, their origin is unusual because they appear not to represent products of a chemically evolved reservoir. In addition, the orientations of the sheets are unusual with respect to similar features elsewhere in the South Mountain Batholith (Horne *et al.*, 1992).

With respect to the overall structural setting and evolution of the sheets, the following points are noted. (1) The sheets are predominantly flat-lying to shallow-dipping and record infilling of subhorizontal dilatant zones in the host granite. Coarse, oriented K-feldspar grains indicate open space infilling and that post-crystallization movement was minimal. The internal evolution and separation of the sheets into fine-grained aplitic bottoms and coarse-grained K-feldspar-rich tops also indicate that the zones of infill must have initially been completely dilatant. The generally flat orientations of the aplite-pegmatite sheets contrast markedly with the subvertical orientations of aplite-pegmatite veins in the South Mountain Batholith. (2) Aplite-pegmatite sheets are very hetereogenous with respect to their internal evolution, and lateral changes in texture and bulk composition are common. (3) Shear-type veins, that is aplites with tapered terminations, are common. (4) The orientations of aplites are at times somewhat similar to conjugate-shear veins. (5) En-echelon arrays of aplites are present. (6) Tourmaline fibres occur at the upper contact of a zoned pegmatite sheet, indicating northeast-directed compression, consistent with the kinematics of the regional Acadian deformation.

Formation of the sheets within monzogranite also indicates that these rocks were deformed by a combined brittle-ductile mechanism. This type of failure in granite does not require complete crystallization, but once a rigid framework is established at 70-75% crystallization the partially solidified magma can deform (Vigneresse *et al.*, 1996). Thus, flat dilatant zones may form in the monzogranite prior to complete crystallization. In order for this to occur, however, special circumstances are involved which predicate high fluid pressures in order to overcome the immense lithostatic pressure generated by the 12-15 km of cover rock at the level of emplacement (MacDonald *et al.*, 1992; Raeside and Mahoney, 1996; Mahoney, 1996). Formation of the dilatant zones, requiring vertical extension, overlapped conditions under which shear-type veins formed (e.g. Fig. 5f). These features are analogous to the subvertical and flat veins observed cross-cutting each other in the Sigma gold mine, Quebec, where periodic buildup of fluid pressure was proposed as a means of forming the contrasting vein arrays (Sibson *et al.*, 1988). Periodic release of fluid from within the magma chamber, generated via exsolution of volatiles, may be a mechanism applicable to Peggys Cove.

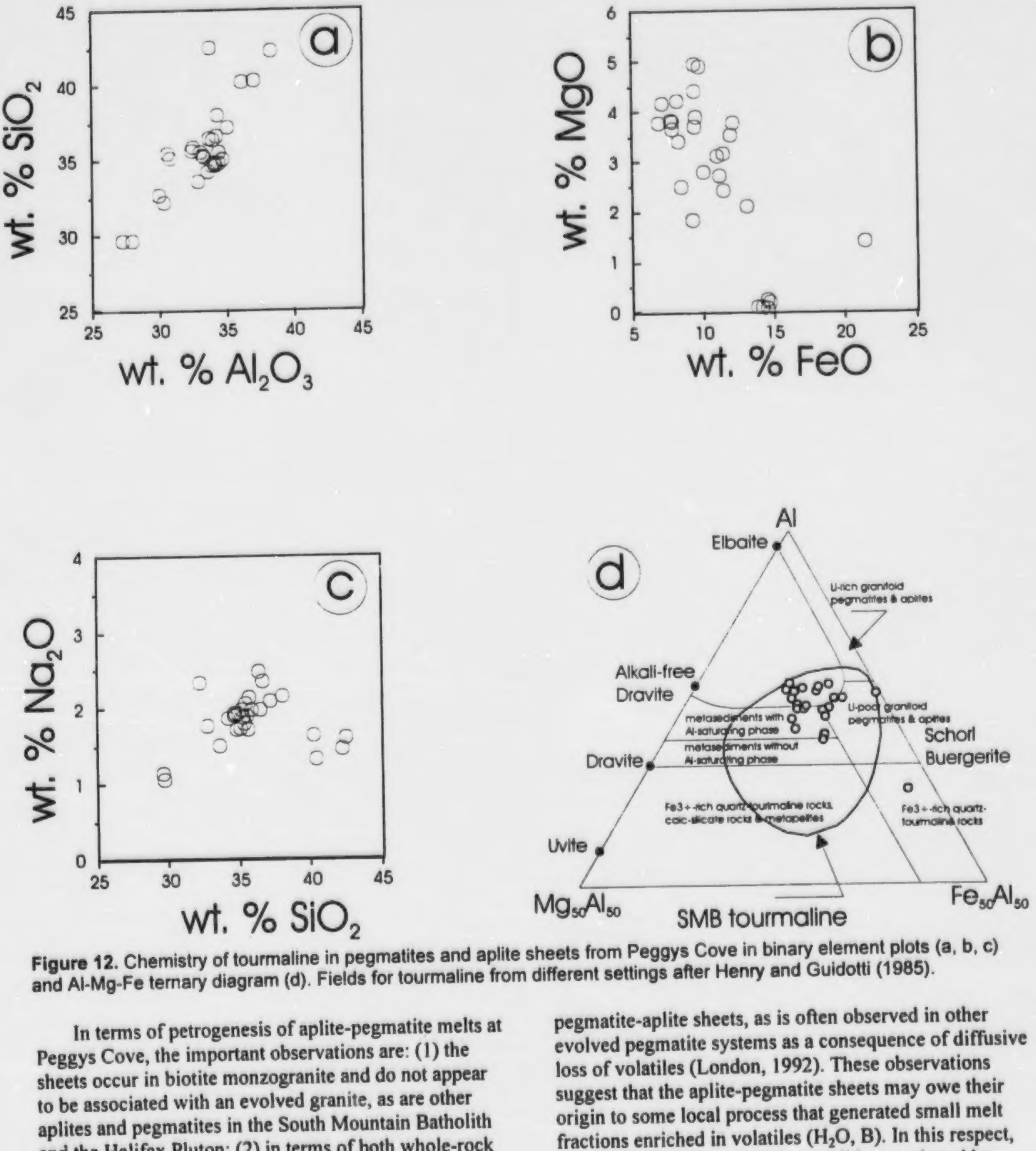

Figure 12. Chemistry of tourmaline in pegmatites and aplite sheets from Peggys Cove in binary element plots (a, b, c) and Al-Mg-Fe ternary diagram (d). Fields for tourmaline from different settings after Henry and Guidotti (1985).

In terms of petrogenesis of aplite-pegmatite melts at Peggys Cove, the important observations are: (1) the sheets occur in biotite monzogranite and do not appear to be associated with an evolved granite, as are other aplites and pegmatites in the South Mountain Batholith and the Halifax Pluton; (2) in terms of both whole-rock and mineral chemistry, the system is not evolved chemically, as (for example) represented by the lack of Rb enrichment in K-feldspar from zoned pegmatites, the low Cl and F contents of muscovite, and the P-poor nature of the alkali feldspars compared to the P-rich nature of feldspars in evolved phases of the SMB; and (3) the absence of any alteration zone around the pegmatite-aplite sheets, as is often observed in other evolved pegmatite systems as a consequence of diffusive loss of volatiles (London, 1992). These observations suggest that the aplite-pegmatite sheets may owe their origin to some local process that generated small melt fractions enriched in volatiles (H_2O, B). In this respect, the presence of melanocratic xenoliths enveloped by pegmatite is considered critical, as they may represent a micro-scale example of the process which formed the larger sheets. A model for this process follows.

Given the proximity of the Meguma Group both laterally (a few hundred metres offshore) and vertically

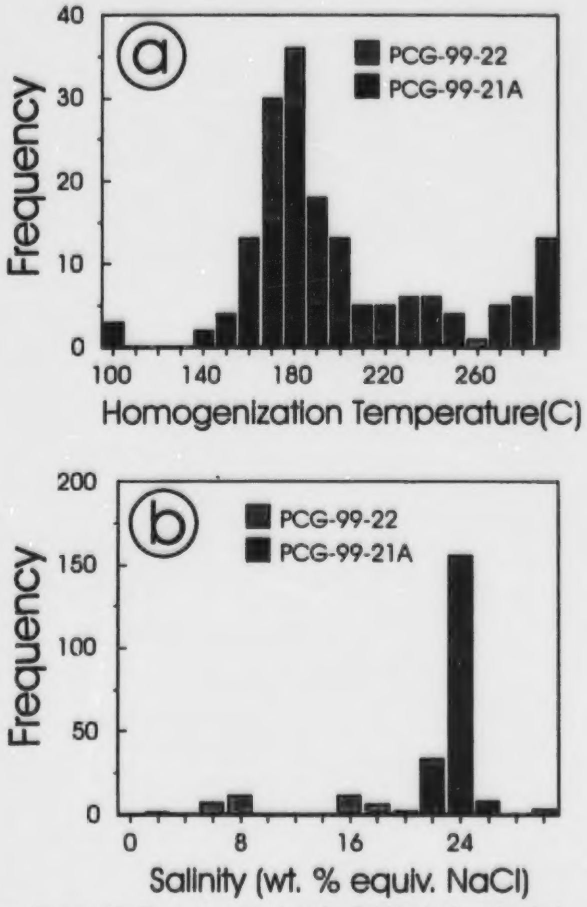

Figure 13. Thermometric data for fluid inclusions hosted by quartz in pegmatite samples from Peggys Cove. (a) Homogenization temperatures (°C). (b) Salinity in wt. % equivalent NaCl.

(proximal to the roof of the intrusion, as indicated by stopped blocks; MacDonald *et al.*, 1992), digestion of Meguma Group xenolithic material would liberate volatiles and locally enrich parts of the melt in H_2O and B. Sudden depressurization of the magma, perhaps in response to regional tectonic processes, would generate small batches of volatile-rich melt. Aplite-pegmatite sheets and their associated internal fabrics are features that are commonly associated with fluctuating water pressure (e.g. Kirkham and Sinclair, 1988; Lowenstern and Sinclair, 1996), as might be expected to occur within an active tectonic regime. Thus, the origin of tourmaline-bearing aplite-pegmatite sheets at Peggys Cove is the result of melt contamination, a model which has been widely accepted and discussed as assimilation and fractional crystallization processes. Additional support for this origin includes: (1) the fluid inclusion chemistry and decrepitate analyses, which together indicate a considerable Ca component to the pegmatitic fluid and the likely derivation of this component from a non-magmatic reservoir given the depletion of calcium in these aplite-pegmatite sheets (an order of magnitude less than sodium and potassium); and (2) preliminary oxygen isotope data for whole-rock samples of aplite which have $\delta^{18}O$ levels of +12 to +13‰. These $\delta^{18}O$ levels are much higher than the +10 to +11‰ generally recorded for granites of the South Mountain Batholith (Kontak *et al.*, 1988, 1991; Clarke *et al.*, 1993) and would be consistent with a contamination model since such $\delta^{18}O$ levels in granites in general indicate the presence of a sedimentary component.

In summary, formation of pegmatite-aplite sheets at Peggys Cove is considered to be contingent on several processes acting in concert. First, a monzogranitic melt was contaminated via partial digestion of Meguma Group metasedimentary xenoliths, which liberated volatiles (H_2O, B) dissolved in the melt. Subsequent depressurization of the area, possibly related to periodic relaxation of the regional forces, caused sudden exsolution of the volatile-enriched melt, which created conditions of sudden overpressuring or hydrofracturing of the partially crystallized (i.e. 75%) melt, resulting in formation of flat dilatant zones. These dilatant zones were immediately infilled by the volatile-rich melt, which subsequently evolved internally to the layered pegmatite-aplite sheets now observed. The undulating nature of the sheets may reflect subsequent folding of these rocks while still ductile.

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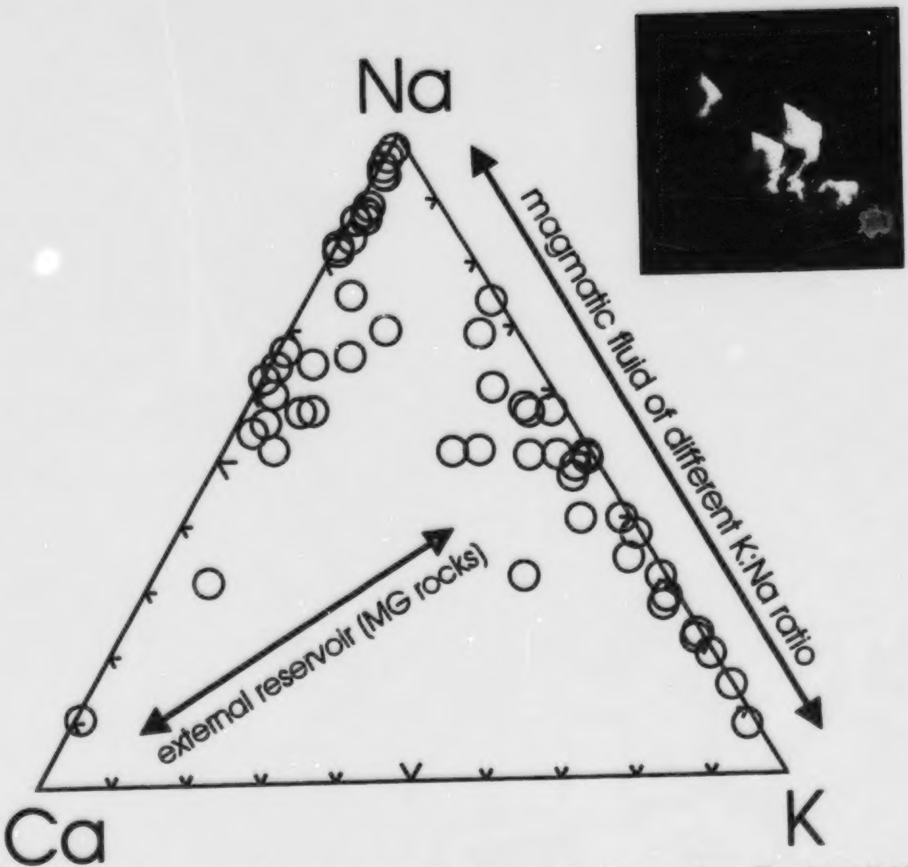

Figure 14. Decrepitates from quartz-hosted fluid inclusions in pegmatites from Peggys Cove. The picture is a back- scattered electron (BSE) image of a decrepitate mound with salt precipitate; the chemistry of such mounds is summarized in the Ca-Na-K ternary diagram. Significance of the two trends noted in the ternary plot is discussed in text.

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Geoscience Editing and Publishing

D. R. MacDonald, B. L. MacDonald, K. A. Mills, J. S. Saunders and A. Miller

Publications play an important role in delivering geoscience information for the Minerals and Energy Branch, educating the public, and conveying the professional image established by the branch. Many times a publication is the first chance we have to make an impression on someone who comes into contact with the Department of Natural Resources.

The role of the geoscience editing and publishing group in the Geoscience Information Services Section can be roughly divided into two parts. The first part involves editing a manuscript (report, article or map) to the author's satisfaction, while at the same time applying the branch standards for style and content in the interest of our readers. Editor Doug MacDonald and contract editor Kathy Mills carry out this work for the Minerals and Energy Branch. The second part involves producing a published document. The editors work with word processing operators Barb MacDonald, Susan Saunders and Angela Miller to produce our branch publications.

Editing

In the Minerals and Energy Branch, all scientific publications must be reviewed by at least one scientist who has not contributed to the research being presented. This process is called peer review and finding a suitable reviewer is usually the editor's first task after receiving a manuscript. The editor assigns the manuscript to a reviewer who is experienced in the field of study being presented by the author. The editor supplies the reviewer with detailed guidelines to direct the review toward the most critical scientific aspects of the manuscript:

1. significance of the content,
2. soundness of the content,
3. completeness of the content, and
4. presentation.

The reviewer's comments are then given to the author so that the manuscript can be revised in an effort to improve its scientific content. Open File Reports and Open File Maps are publications used to release information as soon as possible, and can be approved for release after peer review and minimal editing.

Resubmission of the manuscript after peer review initiates the next step in the editorial process, often called 'substantive' editing. This step may require re-writing parts of the document, re-organizing sections, and generally suggesting ways that the authors can improve the presentation of his or her research for the intended readers. Since the subject matter is geoscience, the editors are geologists. Although the editors cannot be experienced in the particular field of research for each manuscript, they understand the concepts, terminology, and scientific methods employed. The relationship between author and editor is most important during this phase of substantive editing.

Another aspect of the editorial process is often referred to as 'copy' editing. This function requires careful attention to every detail in a document in order to meet the Branch publication standards. For the Minerals and Energy Branch, these standards reflect those used by the Geological Survey of Canada. Some standards, such as consistent capitalization, spelling and punctuation, are easily applied. Others may require much more time and effort, such as accurate citation and listing of references, and making sure that tables, maps and drawings meet the appropriate specifications.

Publishing

The final appearance of our publications is largely determined by the publication team, which includes an editor and a word-processing operator. In the modern age of computer-based publication, the job title 'word processing operator' is an anachronism. This function consists of preparing camera-ready (or Internet-ready) manuscripts for publication, and involves words, figures, tables and other design elements that are electronically composed using a variety of publishing applications, such as WordPerfect® and PageMaker®. Manuscripts travel back and forth between the editor and the word processing operator many times before they are ready to be published, either on paper or on-line.

Staff of the geoscience editing and publishing group work toward the goal of consistent high-quality, timely, and cost-effective reporting on activities carried out by the Minerals and Energy Branch. All geoscientists in the Branch are required to publish accounts of their work. These accounts may be published as scientific reports, memoirs or maps, or they may best be communicated in less technical publications such as information circulars or newsletters. The Branch newsletter *Nova Scotia Minerals Update* is produced quarterly and distributed to approximately 1600 subscribers around the world. The newsletter and many of our other, shorter publications are also converted to HyperText Markup Language (HTML) and are available on-line as part of the Branch web site. These activities ensure that current geoscience information on Nova Scotia is readily available to enhance public awareness and to promote the mineral resources of the province.

The following publications were released in 1999:

Annual Report

Annual Report for the Fiscal Year ending March 31, 1998, by Nova Scotia Department of Natural Resources 1999, 89 pages.

Contribution Series

CS ME 1998-12 Geology of the B Baseline Zone, Walton Cu-Pb-Zn-Ag-Ba Deposit, Nova Scotia, Canada, by D. F. Sangster, M. D. Burtt, D. J. Kontak; *in* Economic Geology, v. 93, 1998, p. 869-982.

CS ME 1998-13 ^{40}Ar/^{39}Ar Dating of Ribbon-Textured Veins and Wall-Rock Material from Meguma Lode Gold Deposits, Nova Scotia: Implications for Timing and Duration of Vein Formation in Slate-Belt Hosted Vein Gold Deposits, by D. J. Kontak, R. J. Horne, H. Sandeman, D. Archibald, and J. K. W. Lee; *in* Canadian Journal of Earth Science, 35 (1998), p. 746-761.

CS ME 1998-14 The Carboniferous Evolution of Nova Scotia, by J. H. Calder; *in* Geological Society, Special Publication 143, Lyell: the Past is the Key to the Present, eds. D. J. Blundell and A. C. Scott.

CS ME 1998-15 Origin and Evolution of the Greisenizing Fluid at the East Kemptville Tin Deposit, Nova Scotia, Canada, by W. E. Halter, A. E. Williams-Jones, and D. J. Kontak, Nova Scotia Department of Natural Resources; *in* Economic Geology, v. 93, 1998, p. 1026-1051.

CS ME 1998-16 Wisconsinan Glacial and Sea-Level History of Maritime Canada and the Adjacent Continental Shelf: A Correlation of Land and Sea Events, by R. R. Stea, D. J. W. Piper, G. B. J. Fader, and R. Boyd; *in* GSA Bulletin, July 1998, v. 110, p. 821-845.

CS ME 1998-17 Stratigraphy and Tectonic Significance of the Lower to Middle Devonian McAdams Lake Formation, Cape Breton Island, Nova Scotia, by C. E. White, and S. M. Barr; *in* Atlantic Geology, 34, p. 133-145.

CS ME 1999-1 Documentation of Variable Trace- and Rare-Earth-Element Abundances in Carbonates from Auriferous Quartz Veins in Meguma Lode-Gold Deposits, Nova Scotia, by D. J. Kontak, S. J. Jackson, Canadian Mineralogist, vol. 37, 1999, pages 469-488.

CS ME 1999-2 Quartz Vein Styles in Turbidite-Hosted Mesothermal Gold Deposits of Western South Island (New Zealand), Victoria (Australia) and Nova Scotia (Canada), by A. B. Chrisite, P. K. Smith, R. J. Ryan, W. H. Ramsay, D. C. Arne, F. P. Bierlein; *in* The Australian Institute of Mining and Metallurgy, 32nd Annual Conference, September 1999, pages 85-108.

CS ME 1999-3 Using whole rock geochemistry to locate the source of igneous erratics from drumlins on the Atlantic coast of Nova Scotia, by Rudolph R. Stea, Nova Scotia Department of Natural Resources, Georgia Pe-Piper, Saint Mary's University, 1999, Boreas, vol. 28, pages 308-325, 7 maps.

Information Circulars

IC ME 59 Properties Available for Option in Nova Scotia, January 1999, a joint project between the Nova Scotia Department of Natural Resources, Minerals and Energy Branch, the Chamber of Mineral Resources of Nova Scotia and the Mining Society of Nova Scotia, 1999, 82 pages.

Open File Maps

OFM ME 1999-1 Index map of Nova Scotia Department of Natural Resources Bedrock Geology, Surficial Geology and Aeromagnetic Open File Maps of Nova Scotia [scale 1:100 000], compiled by K. D. Fraser, 1999, 1 map.

OFM ME 1999-2 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/14], Nova Scotia, by L. J. Ham, 1999, 1 colour map, scale 1:50 000.

OFM ME 1999-3 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/15], Nova Scotia, by L. J. Ham, 1999, 1 colour map, scale 1:50 000.

Open File Reports

OFR ME 1999-1 NTS Location Author and Citation Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, 1996-1998, compiled by Paul D. McCulloch, Sandra Marshall, Norman A. Lyttle and J. Susan Saunders, 1999, 81 pages.

Reports

Report ME 1999-1 Minerals and Energy Branch Report of Activities 1998, edited by D. R. MacDonald and K. A. Mills, 213 pages.

Report ME 1998-2 Mining Matters for Nova Scotia '99: Opportunities for Economic Development, edited by D. R. MacDonald, 1999, 36 pages.

Mineral Exploration Activity in Nova Scotia, 1999

P. D. McCulloch

Introduction

Monitoring of mineral exploration activity in Nova Scotia is coordinated through the Geoscience Information Services Section of the Mineral and Energy Resources Division by the author, who works out of the regional office in Stellarton, Pictou County. Regional Geologists of the Regional Services Branch offices in Coxheath (Don MacNeil), Truro (Ian Lawyer) and Bridgewater (Sandra Marshall) assist in the field monitoring of mineral exploration activity in their respective regions.

The monitoring process covers exploration activities throughout the province and consists of visits to company offices and exploration sites, liaison with industry personnel and review of current assessment reports and other material submitted by industry. Liaison with industry allows the department to maintain an awareness of current exploration activities throughout the province. Assistance or advice is provided as necessary, and any drill core generated by mineral exploration activity is recorded as part of the monitoring process. This core may be recovered for archiving in the Drill Core Library in Stellarton when no longer required by the companies.

The Exploration Monitoring geologist is also responsible for the auditing of confidential assessment reports that are submitted in the support of the renewal of exploration licences. In 1999, 104 assessment reports were received and audited for compliance with the Mineral Resources Regulations.

Mineral Exploration Activity in 1999

In 1999, mineral exploration in Nova Scotia continued at approximately the same level of activity as in 1998. Field exploration expenditures have generally decreased over the past two years, with field expenditures expected in the range of $4-5 million for 1999, compared with $5.6 million in 1998 and $6.7 million in 1997 (Table 1, Fig. 1). Exploration was carried out for industrial minerals, base metals, gold and coal in a variety of geological environments throughout the province.

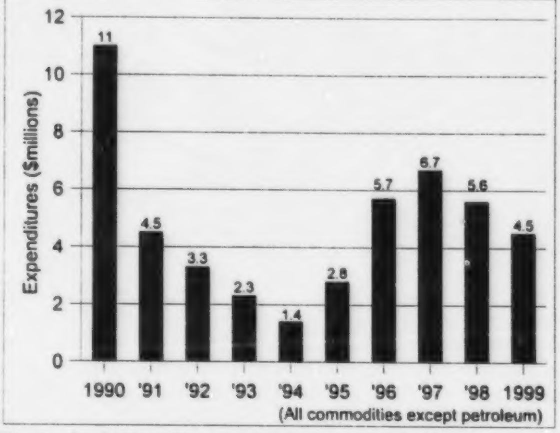


Figure 1. Exploration expenditures in Nova Scotia, 1990-99.

Preliminary figures for the total number of general claims staked in 1999 show a moderate increase of 19.7% from the previous year to 13,067 (Table 1, Fig. 2). A preliminary total of 13,937 claims for all commodities were in effect at the end of 1999, represented by 652 exploration, coal, tailings and special licences covering an area of 225 612 ha or 2 256 km², approximately 4.1% of the total area of the province. The amount of exploration drilling increased moderately in 1999 with a preliminary estimate of 13,300 metres drilled compared with 10 300 metres in 1998 and 24 500 metres in 1997.

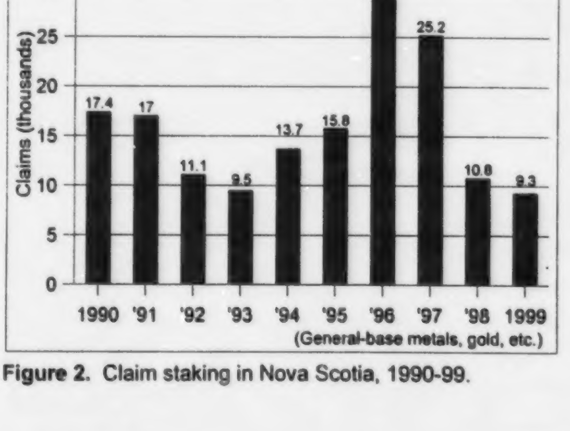


Figure 2. Claim staking in Nova Scotia, 1990-99.

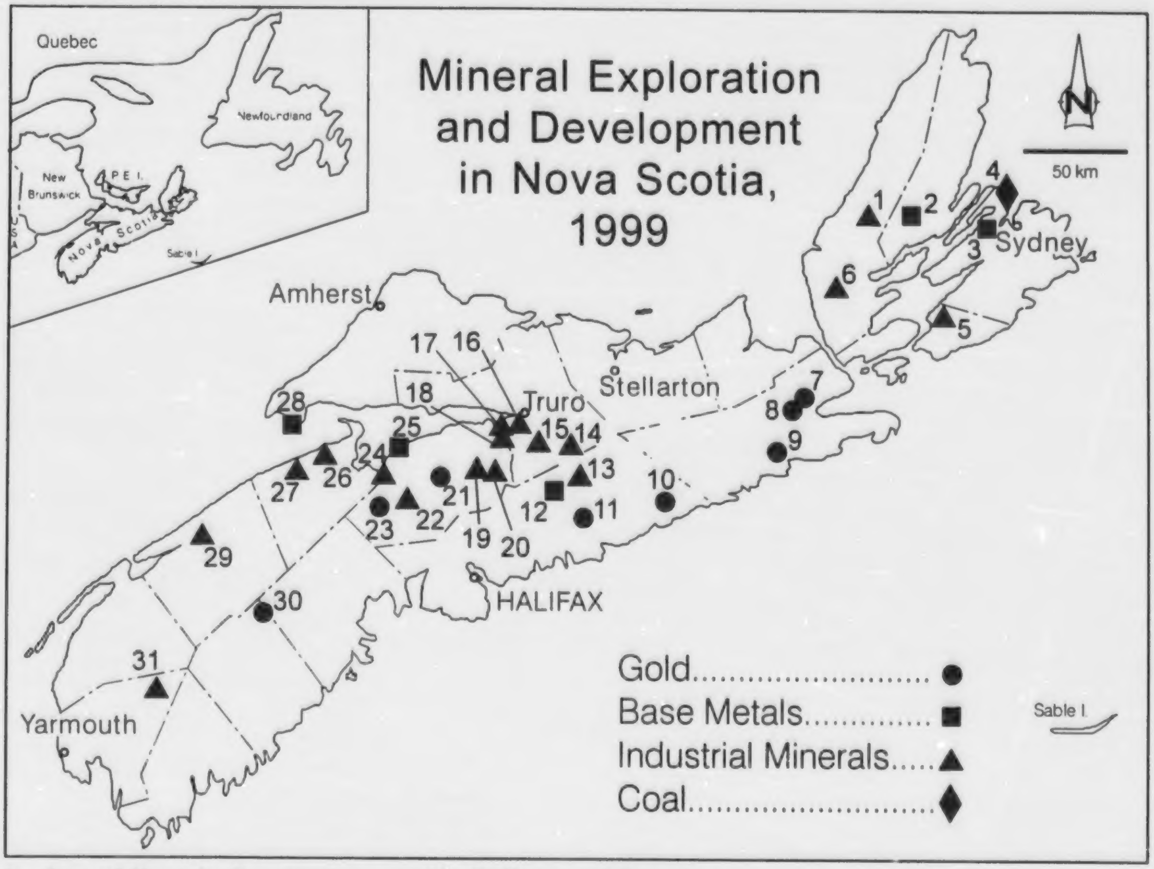
Table 1. Details of exploration and development activity in Nova Scotia, 1990-1999.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	P1999
Total Field Exploration Expenditures ($)	11 025 000	4 532 000	3 300 000	2 300 000	1 400 000	2 843 000	5 752 000	6 700 000	5 600 000	4 500 000
Total Licences Issued (all categories)	753	642	507	593	671	698	1 126	967	700	652
Claims In Good Standing (new and reissued) General	17 460	17 071	11 157	9 504	13 740	15 861	33 339	25 190	10 916	13 067
Special (Order in Council)										
Salt and Potash	298	264	264	66	66	-	16	16	329	74
Coal	2 440	1 566	366	433	376	376	469	398	253	173
Tailings	116	116	94	146	146	146	146	146	-	-
Other	331	448	348	452	255	130	254	254	621	623
Uranium*	(1 200)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)
Development	1 474	553	-	-	-	-	-	-	-	
Total (excluding closures and uranium licences)	22 119	20 018	12 229	10 601	14 583	16 513	34 284	26 004	12 119	13937
Total Area Held Under Licence										
ha	358 062	324 051	197 963	171 609	236 069	267 312	554 988	420 952	196 182	225 612
acres	884 760	800 720	489 160	424 040	583 320	660 520	1 371360	1 040 160	484 760	557 480
Work Reported for Licence Renewals ($)	16 551 636	3 889 914	2 333 972	983 402	1 694 368	1 601 639	2 376 023	3 146 899	5 385 194	296 9047
Number of Assessment Reports Received	176	132	75	62	84	111	114	137	137	104

P Preliminary figures for 1999

* Parentheses around uranium claims indicate ground alienation due to the uranium moratorium

December 31, 1999



1. Lynx Minerals Corporation
2. C. G. Johnson
3. Mount Cameron Minerals Ltd.
4. Brogan Mining Company Ltd.
5. R. MacDonald
6. Kelly Rock Ltd.
7. H. Schenkels
8. H. Schenkels
9. Indocan Resources Inc.
10. Newfoundland Goldbar Resources Ltd.
11. Strikezone Minerals (Canada) Ltd.
12. Savage Zinc Incorporated
13. Kaoclay Resources Inc.
14. Kaoclay Resources Inc.
15. Lafarge Canada Inc.
16. Lafarge Canada Inc.
17. M. Roche
18. Nar Resources Ltd.
19. Shaw Resources
20. Lafarge Canada Inc.
21. R. Anthony
22. J. Richman
23. True Metallic Explorations
24. Hansone Ltd.
25. Geosearch.
26. C_2C Mining Corporation
27. C_2C Mining Corporation
28. Gold'n Crystal Minerals
29. Hibernia Minerals Ltd.
30. L. Jensen
31. Black Bull Resources Inc.

Figure 3. Mineral exploration programs in Nova Scotia, 1999.

Approximately 236 companies and individuals held exploration interests (licences or options) in Nova Scotia in 1999 including 8 major, 7 junior and 45 private companies (Tables 2, 3 and 4). In addition, several mining lease holders carried out exploration on their leases or on unclaimed ground where these commodities did not require licences (e.g. limestone, gypsum). Organizations actively engaged in exploration during 1999 included 6 major, 2 junior and 20 private companies (Fig. 3, Table 5), as well as a number of individuals.

Table 2. Major companies involved in mineral exploration in Nova Scotia, 1997-1999.

	1997	1998	1999	Office location in 1999
BHP Minerals Canada Limited	-	-		
Caledonia Mining Corporation	x			
Canada Tungsten Incorporated (formerly Canamax Resources Incorporated)	-			
Conwest Exploration Company Limited				
A. J. Perron Gold Corporation (formerly Deak Resources Corporation)	x	x		
Falconbridge Limited	-	-		
Fundy Gypsum Company	x	x	x	Windsor
Georgia Pacific Corporation	x	x	x	Sugar Camp
Granges Exploration Limited	-			
Lafarge Canada Incorporated	-	-	x	Brookfield
Little Narrows Gypsum Company Limited	x	x	x	Little Narrows
National Gypsum (Canada) Limited	x	x	x	Milford Station
Noranda Exploration Company Limited	-	-	-	
Phelps Dodge Corporation of Canada Limited	x	x		
Placer Dome Canada Limited				
Savage Resources Canada Limited	x	x	x	
W. M. C. International Limited	-	-	-	

x indicates work performed
- company inactive
blanks indicate that the company did not hold an exploration licence in that particular year

Industrial Minerals

Exploration and development work for industrial minerals was highlighted by the continuation of interest in several commodities including kaolin, silica sand, limestone, gypsum, zeolites, titanium and barite. Work continued to focus on the exploration and development of extensive Cretaceous kaolin and silica sand deposits in central mainland Nova Scotia, and the titanium-bearing heavy mineral sand deposits along the Shubenacadie River and in the Cobequid Bay area.

Kaoclay Resources Incorporated continued a detailed evaluation of Cretaceous kaolin and silica sand deposits in the Musquodoboit and Shubenacadie valleys of central mainland Nova Scotia. The company carried out extensive process testing on large-diameter core samples and completed additional diamond-drilling in the Middle Musquodoboit area. Black Bull Resources Incorporated, under an option agreement with CAG Enterprises Limited, continued a detailed exploration program for kaolin along the Tobeatic Fault Zone on the southern margin of the South Mountain Batholith in the Flintstone Rock area, Yarmouth County. Work consisted of trenching and diamond-drilling. Hibernia Minerals Incorporated also completed a drilling program for kaolin along the northern margin of the South Mountain Batholith at West Paradise, Annapolis County.

C_2C Mining Corporation are continuing a detailed evaluation of the zeolite potential of Triassic amygdaloidal basalts along North Mountain in western Nova Scotia. The company completed geological mapping, diamond-drilling, and extensive analytical work on several properties in the area and recently carried out a bulk sampling program and process testing on a zeolite occurrence in the Stronach Mountain area.

Table 3. Junior exploration companies in Nova Scotia, 1997-1999.

	1997	1998	1999	Office location in 1999
Altai Atlantic Mining Incorporated	x			
Acadia Mineral Ventures Limited	-			
Alterra Resources Incorporated (formerly Medyx Incorporated)				Truro
Ashgrove Energy Limited				
Atlantic Industrial Minerals Incorporated	x			Sydney
C_2C Mining Corporation	x	x	x	Kentville
Corner Bay Minerals Incorporated	-	-	-	Cold Brook Station
Exploration Orex Incorporated	-	-		
Globex Mining Enterprises Incorporated	-	-	-	
Groundstar Resources Limited	-	-		
Heartland Resources Limited	-	-	-	Dartmouth
Jascan Resources Incorporated	-			
Mispec Resources Limited	x			Truro
Regal Goldfields Limited	x	x	-	
Roycefield Resources Limited	-	-	-	
RJZ Mining Incorporated	x	x	x	

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration licence in that particular year

NAR Resources Limited, under an option agreement with Titanium Corporation of Canada Limited, initiated a detailed evaluation of the titanium potential of heavy mineral sands in the Shubenacadie River near South Maitland, Hants County, in 1998. The company continued detailed work on the property in 1999 including extensive drilling and mineralogical analyses of the titanium-bearing sand deposits. Mr. Martin Roche, in association with Hansone Limited, intiated a detailed evaluation of the the heavy mineral potential of sand deposits in the Cobequid Bay area near Maitland, Hants County, and in the Avon River area near Windsor, Hants County. Detailed mineralogical studies and drilling were continued on the two properties in 1999.

Exploration drilling for limestone was carried out during the year by Lafarge Canada Incorporated in the Hardwoodlands area in Hants County, and the Brentwood and Beaver Brook areas in Colchester County. Shaw Resources also completed a diamond-drilling program in the Hardwoodlands area, Hants County, and Kelly Rock Limited completed additional work on the Glendale limestone deposit in Inverness County, consisting of trenching and detailed rock sampling.

A diamond-drilling program was completed by Mr. Robert MacDonald at Lochside, Richmond County, to evaluate the resource potential of the former Novex Mining Pine Brook barite deposit.

Base Metals

Exploration for base metals continued at approximately the same level of activity as in 1998 and focused primarily on areas of known mineral occurrences in several areas of the province.

A diamond-drilling program was undertaken by Mount Cameron Minerals Limited to evaluate the base metal potential of skarn zones associated with Precambrian carbonates in the Georges River and Mount Cameron areas of the Boisdale Hills in Cape Breton County. Savage Resources Canada Limited completed geophysical survey work on the company's Glenmore property in Halifax County to evaluate the Pb-Zn potential of underlying Lower Carboniferous Windsor Group carbonates. Geosearch completed detailed geochemical work on a base metal prospect near Lower Burlington, Hants County, and Gold 'n Crystal Minerals completed additional work to evaluate the gold and base metal potential of the Triassic volcanics at Cap d'Or, Cumberland County.

Table 4. Private exploration companies in Nova Scotia, 1997-1999.

	1997	1998	1999	Office location in 1999
AEC West Limited	-			
Asedex Minerals Corporation Limited			-	
Aurora Gold Corporation	-			
Aurion Minerals Limited				Halifax
Beaver Exploration Incorporated	-			
Benrock Limited				Antigonish
Berichan Resources Limited	x			
Broad River Exploration			-	
Burnt Point Resources Incorporated	x	x	x	Halifax
C.A.G. Enterprises Limited	x	-	x	Antigonish
Cannova Goldfields Incorporated	x		x	
CAN-SCO Enterprises	-			Halifax
Cape Minerals Limited		-	-	
Champlain Goldfields Incorporated	-			
Champlain Resources Incorporated	x	-	-	
Cobequid Life Sciences Limited	-	-	-	
Conrad Brothers Limited	-		-	Dartmouth
D&D Metal Detectors Limited	-			
D. R. Duncan & Associates Limited			-	
Datum Quest Explorations			x	
Dufferin Resources Incorporated	-	-	x	Halifax
Ellsin Resources Incorporated	x	x	x	
Gallant Aggregates Limited	-			
Gammon Lake Resources Incorporated	x	x	-	Halifax
Geocol Mining and Exploration	-			Dartmouth
Geosearch	x	x	x	Sackville
Ghost Town Gold Corporation	-			
Giant Meguma Holdings	-	-	-	Halifax
Gold Bank Resources Limited	-			
Gold 'n' Crystal Minerals	x	x	x	East Advocate
Golden Ace Mineral Explorations Limited	-	x	x	
Goliath Copperfields Limited	x	-		
Groundstar Resources Limited	-	-		
Gusto Resources Limited	-	-		Halifax
H & E Mullen Investments Limited			-	
Halifax Goldfields Incorporated	-			
Hansone Limited	-	x	x	
Hibernia Minerals Incorporated			-	
Highland Range Minerals Limited	x	x	-	
Huntington Explorations Incorporated		-	-	
Intragaz & Company Limited Partnership		-		
James Henry & Associates	-	-		
John Logan Enterprises Limited	-	-	-	
Jubilee Minerals	-	x	x	Bedford
Kaoclay Incorporated	x	x	x	Milford Station
Kelly Investments Limited			-	
Kelly Rock Limited	-	-	x	Sydney
Lake Annis Properties Limited		-		
Little Lake Gold Mines Limited	x	-	-	Dartmouth
Lodestone Limited	-			Halifax
Lynx Minerals Corporation			x	
Maritime Mica Incorporated		x		
Mercator Geological Services Limited		x	x	Dartmouth
Mik Vic Investments Limited	-			

Table 4. Continued.

	1997	1998	1999	Office location in 1999
Minas Basin Pulp & Paper Company Limited			-	
Moose River Resources Incorporated	x			
Mosher Limestone Company Limited	-			Upper Musquodoboit
Mount Cameron Minerals Incorporated			x	
Mountain Lake Resources Incorporated		-		
Murray Brook Resources Incorporated	-			
New Road Resources Limited		-		
North Cape Breton Resources Limited	-	x	-	
Ochter Holdings Limited			-	
Pan East Petroleum Corporation (formerly Pan East Resources Incorporated)	-	-	-	
Prodigy Resources Incorporated	x			
Rainbow Resources Limited			-	
Remoscan Limited	x	-	x	
Renfrew Gold Contracting	x			
Renfrew Holdings Limited		-		
The Shaw Group Limited (formerly L. E. Shaw Limited)	-	-	-	Lantz
Scotia Slate Products Limited	-			
Southfield Resources Limited	-			
Springhill Coal Mines Limited				
Strikezone Minerals (Canada) Limited		x		
Tangier Limited Partnership (formerly Tangier Mining Incorporated)	x	x	-	Tangier
Tanner Engineering Limited				
Tri-Explorations Limited	x	x	-	Halifax
True Metallic Explorations	x	x	x	
Tusket Mining Incorporated	x			Bedford
Uravan Minerals Incorporated			-	
Victoria Mining Services Limited	-			
Votix Corporation Limited	x	x	x	Trenton
Wabana Explorations Incorporated	x			

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration licence in that particular year

Table 5. Exploration programs in Nova Scotia, 1999.

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM	STATUS
Black Bull Resources Incorporated	Flintstone Rock, Yarmouth County	Clay	Diamond-drilling	Ongoing
Brogan Mining Company Limited	Little Pond, Cape Breton County	Coal	Bulk sampling, development work	-
C_2C Mining Corporation	Stronach Mountain, Annapolis County	Zeolites	Diamond-drilling, analytical work	Ongoing
C. Gaye Johnson	McLeod Brook, Victoria County	Gold, base metals	Soil geochemistry	Ongoing
Geosearch	Cheverie, Hants County	Base metals	Prospecting, geochemical sampling	Ongoing
Gold 'n' Crystal Minerals	Cap d'Or, Cumberland County	Copper, gold	Prospecting, geochemical sampling	Ongoing
Henry Schenkels	Forest Hill, Guysborough County	Gold	Data compilation	Ongoing
	North Ogden, Guysborough County	Gold	Prospecting, rock geochemistry	-
Hibernia Minerals Limited	West Paradise, Annapolis County	Clay	Diamond-drilling	-
Indocan Resources Incorporated	Isaacs Harbour, Guysborough County	Gold	Diamond-drilling	-
Joe Richman	Three Mile Plains, Hants County	Clay, silica sand	Prospecting, geochemical sampling	Ongoing
Kaoclay Resources Incorporated	Middle/Upper Stewiacke	Clay, silica sand	Diamond-drilling	Ongoing
	Middle/Upper Musquodoboit	Clay, silica sand	Diamond-drilling, bulk sampling	Ongoing
Kelly Rock Limited	Glendale, Inverness County	Limestone	Trenching, rock sampling	Ongoing
Lafarge Canada Incorporated	Hardwoodlands, Hants County	Limestone	Diamond-drilling	-
	Brentwood, Colchester County	Limestone	Diamond-drilling	-
	Beaver Brook, Colchester County	Limestone	Diamond-drilling	-
Lynden Jensen	Brookfield Mines, Queens County	Gold	Geological mapping, geochemical sampling	
Lynx Minerals Incorporated	Scotsville, Inverness County	Barite	Bulk sampling, development work	Ongoing
Martin Roche/Hansone Limited	Cobequid Bay, Hants County	Mineral sands	Drilling, mineralogical studies	Ongoing
	Avon River, Hants County	Mineral sands	Drilling, mineralogical studies	Ongoing
Mount Cameron Minerals Limited	Mount Cameron, Cape Breton County	Base metals	Diamond-drilling	
NAR Resources Limited	Shubenacadie River, Hants County	Mineral sands	Drilling, geochemical sampling	Ongoing
Newfoundland Goldbar Resources Inc.	Dufferin Mines, Halifax County	Gold	Diamond-drilling	-
Robert MacDonald	Lochside, Richmond County	Barite	Diamond-drilling	-
Roland Anthony	McKay Section, Hants County	Gold	Trenching	Ongoing
Savage Resources Canada Limited	Glenmore, Halifax County	Base metals	Geophysical surveys	-
Shaw Resources	Hardwoodlands, Hants County	Limestone	Diamond-drilling	-
Strikezone Minerals (Canada) Limited	Lake Charlotte, Halifax County	Gold	Geological mapping	Ongoing
True Metallic Explorations Inc.	Upper Falmouth, Hants County	Gold	Prospecting, geological mapping	Ongoing

Gold

The lower Paleozoic Meguma Group of southern mainland Nova Scotia continued to be a focus for gold exploration in the province. The level of activity for gold exploration has declined significantly since 1997.

A diamond-drilling program was undertaken by Newfoundland Goldbar Resources Incorporated in the vicinity of the former Dufferin Gold Mine at Dufferin Mines, Halifax County, to evaluate the potential for gold-bearing saddle reef structures to occur at depth. Indocan Resources Incorporated conducted an exploration drilling program for gold on the North Star gold mine property at Isaacs Harbour, Guysborough County. The company also re-opened and rehabilitated the former #2 access ramp into the old workings. A number of small exploration programs were also completed on several properties throughout the Meguma Group by various individuals and private interests.

Coal

Exploration for coal continued in the Carboniferous rocks of northern mainland Nova Scotia and eastern Cape Breton Island. Berichan Resources Limited continued a detailed evaluation of coal resources in the Cottam Settlement area east of Debert, Colchester County, and began mining operations on the property in June 1999. Brogan Mining Company Limited completed a bulk sampling program for coal at Little Pond, Cape Breton County, early in the year.

Drill Core Library Programs in 1999

J. M. McMullin, D. Weir and J. Horton

Introduction

The departmental Core Library is based in Stellarton, Pictou County (NTS 11E/10), where a modern facility houses most of the department's drill core. Drill core and other sample materials are received from mineral exploration and development projects conducted by the private sector as well as from departmental field work. A large collection of drill core and other reference material is preserved and made available to exploration and research geologists, to enhance the knowledge of Nova Scotia's geology and mineral resources by further study and analysis of the core and other samples, in conjunction with their field, laboratory and office studies. In addition to drill core, sample media available for further work include well-cuttings from oil and gas drilling, rock slabs and geochemical samples (silt, till, soil, lake sediment and biogeochemical samples). All core is available for examination by interested parties and may be sampled subject to certain constraints. Logs, reports and maps are also available for consultation. It is recommended that all visitors give advance notice (preferably a minimum of 24 hours) of an intended visit to ensure the availability of staff, core and equipment. Staff may be contacted by phone at **902-752-4842** or **902-755-7038**, by fax at **902- 755-7186** or by e-mail at **corelib@fox.nstn.ca**.

Facilities and Services

The main Core Library facility is centrally located in Nova Scotia, 2 km off the Trans-Canada Highway at 105-109 Acheron Court in the Stellarton Industrial Park, Pictou County. Five purpose-built buildings total 4000 m^2, which includes 300 m^2 of laboratory space and 120 m^2 of office space. Free parking is available at the gate. Unmanned storage buildings are located at West Paradise (the Eden Building) near Bridgetown, Annapolis County, and in the Scotia Subdivision of the Debert Industrial Park, Colchester County.

Most of the core is stored in standard wooden boxes or trays (5 ft. long) that have capacities of 15 to 25 feet of core, depending on the core diameter. Boxes of core are stored on custom-made wooden pallets which are then stacked in rows in the storage areas. The storage areas only have basic lighting and are unheated. When required, individual pallets are retrieved from storage and transferred by fork-lift to the core examination labs, where the core boxes may be laid out for viewing, using benches, portable stands or the floor. A large paved yard also serves as a core box layout area during good weather. The Core Library is equipped with binocular microscopes, hand held UV lights, photographic equipment, scales, core-splitters and diamond saws.

A small reference library area is set up on the ground floor with tables, chairs and a microfiche reader-printer, available for the use of both clients and staff. All nonconfidential assessment reports and all open file reports, open file illustrations and open file maps are available on microfiche, and paper copies of most of the reports, papers, maps and other minerals-related Nova Scotia Department of Natural Resources (NSDNR) publications are available for reference.

Two interlinked PC-based databases contain information related to drilling done in the province and to the drill core that is held in the Core Library. These databases are maintained by staff at the Core Library, and can be searched by clients on a public access computer. Drillholes with known geographic co-ordinates can also be displayed as map plots (video screen or print) using the department's ArcView®-based geographic information system (GIS).

To ensure Y2K compliance, most of the Core Library desktop computers were replaced late in 1999 with the new standard desktop machines (Pentium II, 400 mHz with 64 Meg RAM). Standard software includes Corel Suite 8, Netscape Communicator and Pegasus (e-mail). The public access computer also allows clients to access the Minerals and Energy Branch GIS and the Mineral Occurrence Database and also limited use of the internet to access departmental web pages and e-mail.

The move out of the Mines Building in Stellarton was completed in 1999, with disposal of the remaining surplus furniture and equipment, and renovations to the Core Library began early in 1999. Staffing changes at the Core Library in 1999 included the transfer of Shirley Ross (clerk/receptionist) to the Stillwater office (NSDNR Regional Services) and the retirement of Jim DeWolfe. At year-end, technical and professional staff operating the Core Library programs consisted of a mineral technologist, a project geologist and a supervising geologist. Two geology students from St. Francis Xavier University (Heather Sutherland and Andrew MacLeod) were employed from June to August.

Holdings And New Acquisitions in 1999

Total core in storage in all locations at the end of 1999 was approximately 642 000 m. In addition to core, the Core Library maintains a set of drill cuttings (chips) from many of the wells drilled for oil and gas in Nova Scotia and its offshore areas. Also, a great variety of different types of samples and sample collections are stored in Core Library facilities, ranging from materials collected in the field by staff, including geochemical sample suites, rock slabs and till samples, to collections of soil and rock samples donated by exploration companies. Core donated to the department is sometimes delivered by the donating company, but more often the core is collected from its field location by Core Library staff using departmental vehicles.

In 1999, 2197 m of drill core from 39 drillholes were received at the Core Library. The core was generated from mineral and gas exploration work carried out by the private sector in 1988, 1998 and 1999, and from geotechnical evaluation work for a new highway carried out by the Department of Transportation and Public Works in 1999 (Table 1).

1999 Activity

Clients included private sector geologists working in the minerals exploration and development sectors and the oil and gas sector, as well as geologists with the Geological Survey of Canada and NSDNR (Mineral and Energy Resources Division), prospectors and academic geoscientists. The level of client activity at the Core Library facilities during 1999 increased from 1998 and was one of the busiest years this decade.

Core Library Databases and GIS

The Core Library maintains two databases containing information on drilling in Nova Scotia, the Drillholes Database and the Drill Core Database.

The Drillholes Database provides information on drilling related to mining, mineral or hydrocarbon exploration and development, or geological investigations. The database provides basic information on each drillhole, such as location (including claim reference map, tract and claim, latitude and longitude, and UTM co-ordinates), depth of hole, year drilled, exploration company, drilling contractor, types of mineralization, and references to assessment reports and other source documents. This database is continuously updated with information from newly released assessment reports and other sources.

The Drill Core Database provides information on all drill core that the Core Library has in its collection, including operational data such as the storage location details and a record of usage and sampling. Much of the basic drillhole information is common to both databases, so they have been linked electronically for greater efficiency.

These databases can be custom searched by any combination of fields to produce either a printed hard copy or an electronic file with the required information. For example, the databases may be searched by place name, company name, hole number, map sheet, mineralization or year, or by various combinations of

Table 1. Drill core received at the Core Library, January 1st to December 31st 1999.

NTS	Company	Year Drilled	Commodity or Project	Location	Holes	Hole Designation	Core Size	Total (m)	Total (ft.)
11D/13C	Nova Scotia Dept. of Transportation and Public Works	1999	sulphides (acid-generating rock)	Highway 101, 2 km east of Ellershouse	19	by grid locations	BQ	142.6	468
11E/03C	Hunt Oil Company Inc.	1999	natural gas	Alton, Colchester County	1	Hunt Alton 1-99	95 mm	6.6	21.6
11K/01C	Mount Cameron Minerals	1999	base metals	Mount Cameron, Cape Breton County	6	MC-99-01 to -06	NQ	854	2802
11K/10C	Regal Goldfields Limited	1998	gold	Faribault Brook, Inverness County	10	RG-1-98 to RG-9-98	NQ	1094	3589
20P/15C	Little Lake Gold Mines Limited	1988	gold	Broad River, Queens County	3	LL-88-01 to -03	BQ	100	328
				Totals	**39**			**2197.2**	**7208.6**

these fields. An application has been set up on the public access computer using OpenInsight® for Workgroups software (Revelation Technologies) which facilitates information searches in the Drillholes and Drill Core Databases by the use of on-screen prompts.

The Drillholes Database is maintained and revised by Donald Weir. At the beginning of 1999 the database contained 21,314 drillhole records. During the year approximately 325 drillholes were indexed from newly released assessment reports. These records, together with 127 previously outstanding records, will be added to the database following completion of proofing and verification; this work was in progress at year end.

The Drill Core Database is updated frequently, with a total of 74 additional records added during the year. At the end of December 1999 it contained 7350 records of which 4693 are linked with the Drillholes Database. Where records are linked or related, the information in both databases on a particular drillhole can be accessed through either database. Some records remain unlinked because the lack of documentation in assessment or open file reports precludes their inclusion in the Drillholes Database.

The Minerals and Energy Branch public access geographic information system (GIS) is in use at the Core Library and was upgraded to ArcView® version 3.1 at the end of 1999. The Drillholes and Drill Core database files have been added to ArcView® as dBASE files (tables). Drillholes can be plotted in ArcView® using Eastings and Northings as x and y co-ordinates. Digital versions of the 1:500 000 Geology Map of Nova Scotia and the 1:50 000 NTS maps are available for use with the Drillholes Database. The Drillholes Database can be searched in ArcView® from any of the fields or by geographic features on the maps. The holes of interest can be highlighted on these maps and this information and the map can be printed on a Hewlett-Packard DesignJet 250C plotter providing plots up to 22 x 34 inches.

A Prospecting Model for Recognition of VLF-EM Signatures in Macumber Formation Rocks in the Walton Area (NTS 21H/01), Hants County

R. F. Mills

Introduction

There is little published information regarding geophysical signatures for mineralized Macumber Formation rocks in the vicinity of base metal and barite occurrences at Walton, Nova Scotia. The Walton Ba-Cu-Pb-Zn-Ag deposit yielded 4.5 million tons of 90% $BaS0_4$, 2.8 million oz. Ag, 1.3 million kg Cu, 9.5 million kg Pb, and 4.4 million kg of Zn (Boyle, 1972). The area remains one of the most important base metal and barite exploration targets in the province.

There are several other known mineral occurrences in the area (Fig. 1). These include two former producers, the Tomlinson Mn mine, approximately 3.6 km south of the Walton mine site in the vicinity of Wade Lake (Hughes, 1995a), and the Sturgis Mn mine (Hughes, 1995b), approximately 1.2 km south of the Walton mine site. The Sturgis manganese mine produced 26 tons of high grade manganese ore prior to 1820. The Feuchtwanger mine was a small producer as well, producing 15 tons of high grade pyrolusite in the early 1800s (Hughes, 1995c). This showing is also documented as a barite occurrence (MacLeod, 1995). The Three Kilometer showing, named for its position 3 km south of the Walton mine site, was discovered during the 1999 field season by prospector John MacIsaac (Mills, 1999). Recent trenching of the site revealed abundant, massive, Fe-Mn zones in north-trending fractures in Horton Group sediments. It appears the fractures were conduits for fluid migration and siderite deposition in the coarse- to fine-grained (Horton Group) sandstone.

In the fall of 1999 several lines were surveyed to collect very low frequency - electromagnetic (VLF-EM) data in the vicinity of the Walton Mine. Data from these lines were examined for a geophysical signature that could be attributed to the Macumber Formation and thus used when prospecting for this important host rock. Distribution of the Macumber Formation is largely inferred and exposure in the area is very poor (Moore, 1986). Therefore, lines were run in the vicinity of the former Walton Mine, where the position of the Macumber Formation is known from past work (Boyle, 1972). The Macumber Formation is the main target of this study since this rock formation hosted the mineral deposit which was the focus of historical production from Walton. It consists largely of finely interbedded to amorphous, dark limy shale, void of fossils. It represents deposition of pelagic organic material mixed with fine-grained suspended sediment that settled out in a (relatively) deep water, near-shore basin, which developed in a warm (Carboniferous) climate.

Field Methods

Two survey lines (line zero and line 50 east) approximately 100 m north of the edge of the Walton open pit mine site were run for 200 meters at an azimuth of 320° over a former ore dump (Fig. 1). A third line was surveyed following the same grid, 200 m east of line zero (line 200 east) in the vicinity of Rainy Cove Brook. Two lines were surveyed southwest of the open pit with the northern extension of the lines terminating near the main shaft of the former (Walton) mine. These lines ran for 150 m at an azimuth of 345°. The reason for this (azimuth) difference is the strike of bedding in the Macumber Formation, which is known to be slightly different in this locality. All survey lines were flagged and measured for distance with a thread meter. The actual location of mineralized Macumber Formation rocks away from the immediate area of the Walton mine site is largely unknown. This is due to a cover of thick glacial drift, which is common to Nova Scotia in general and Hants County in particular (Stea *et al.*, 1992). Recording stations along these lines were 10 m apart to provide high resolution VLF-EM data. If a distinct signature could be recognized, it could be applied to other areas for the purpose of prospecting.

Signature information from this test was compared to information collected on two grid lines surveyed in the immediate vicinity of the Three Kilometer showing where two lines were run on at an azimuth of 110° for a distance of approximately 1 km (tie lines 1000 and 1380; Fig. 1). Stations on these lines were placed 25 m apart. The Macumber Formation is assumed to underlie this area (Fig. 1).

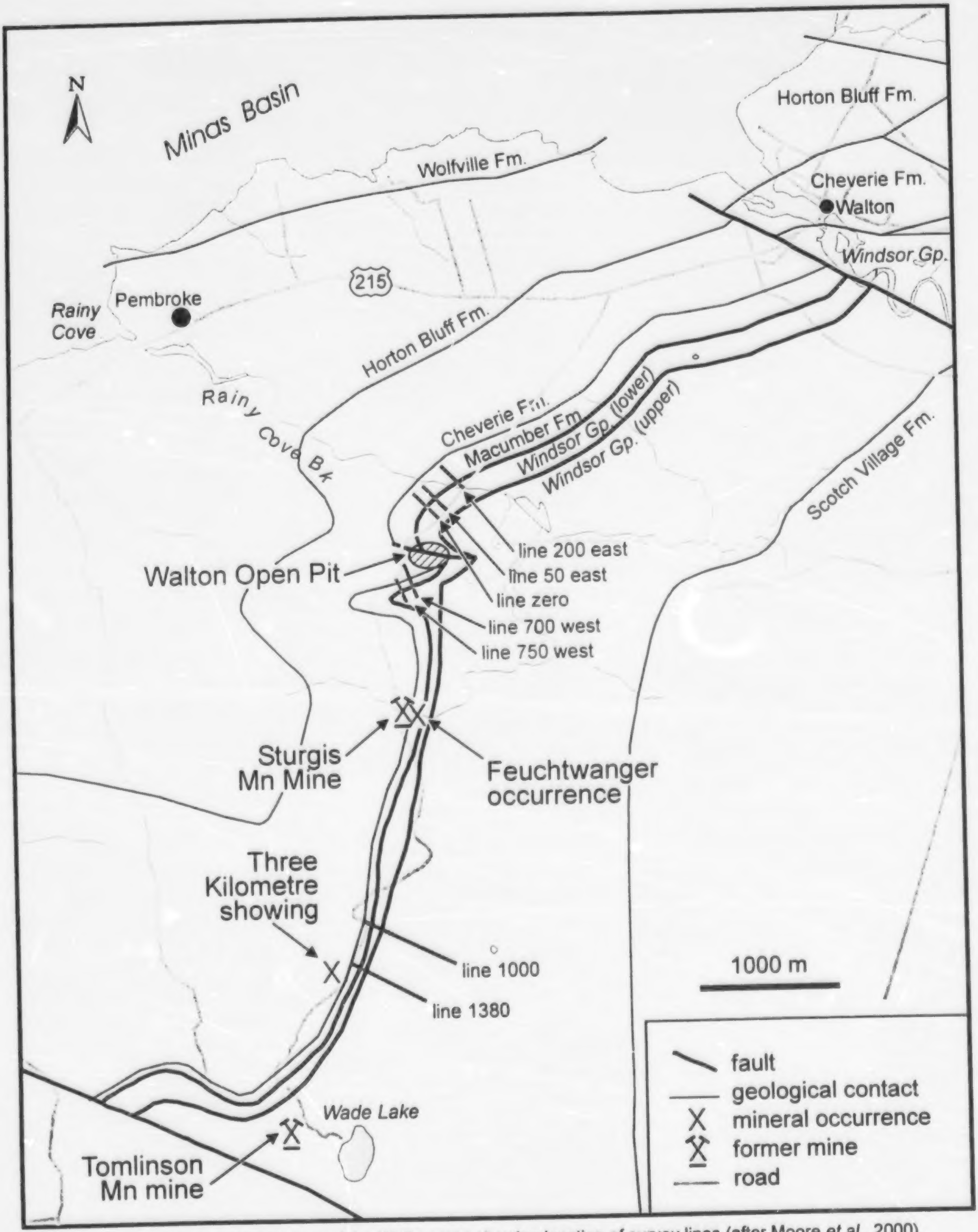


Figure 1. Simplified geological map of the Walton area showing location of survey lines (after Moore *et al.*, 2000).

Readings were taken with a Geonics VLF-EM (EM-16). Data recorded included the in-phase dip angle in degrees (the "dip") and the quad-phase dip angle in degrees (the "quadrature"), components of the vertical magnetic field.

Data Processing

Raw data were analyzed using Quattro Pro® spreadsheets (Appendix, "A") and charts. Data were plotted with the survey line length represented along the x axis and the angle of the in-phase and quad-phase dip represented on the y axis. True crossovers appear as rises in quadrature past the dip angle or, conversely, falls in the dip angle past the angle of quadrature values. The opposite of this (a fall in quadrature past the dip or a rise in dip past the quadrature) is a false crossover, or the result of the EM pointing away from a field of diminishing strength toward a new field of greater strength as a line is traversed, as opposed to crossing over a true magnetic target.

Results

The results of the three survey areas are discussed below and the data are presented in Figures 2, 3 and 4.

Walton Mine Site North

In the vicinity of the Walton mine site north, the first in-phase crossover on line zero east occurs at station 40 north as a relatively weak crossover (Fig. 2). This is accompanied by a weak quadrature crossover at the same station. A second positive quadrature crossover occurs on station 150 north. The quadrature and in-phase dip angles are similar to one another between stations 70 and 120 north as well. The quadrature crossover to accompany the in-phase crossover on line 200 east is also separated by 15 m (quadrature crossover at station 55 as opposed to station 70 north for the in-phase reading). The quadrature response exhibits a similar pattern as the in-phase data, but with an exaggerated response and lower dip angles than the in-phase data.

Walton Mine Site South

In the vicinity of the Walton mine site south, there is a strong crossover on line 700 west at station 70 south (Fig. 3). On line 750 west a moderate crossover spans the line between stations 90 and 120 south. Data for stations on line 750 west follow the same pattern between the in-phase and quadrature dip angles for line 700 west, considering that the in-phase and quadrature dip angles also crossover. However, data for line 700 west display more variability and complexity in the signature for that line.

Three Kilometer Showing

Data from the 3 kilometer showing (Fig. 4) show tie line 1000 displaying two crossovers at stations 925 and 1550 south. Tie line 1380 exhibits a quadrature crossover that spans the length of the line from stations 1550 to 1700 south. The in-phase and quadrature data also exhibit a strong affinity for readings between stations 1300 and 1550 south and between 1900 and 2000 south, as well as an in-phase crossover at station 1950 south.

Discussion

Plots of the VLF-EM data reveal relatively complex patterns composed of signals from numerous sources. In the vicinity north of the Walton mine site there is an in-phase crossover signature for line zero east at station 40 north. This signature is presumably mineralized Macumber Formation, as it is accompanied by a negative quadrature response, a feature indicative of sulphide enrichment (Geonics, 1980). However, this type of signature could also be received in an area where there is an abrupt, severe change in the depth of overburden (Telford *et al.*, 1977). It is recommended that resistivity data be collected over these lines in future to clarify this possibility. It has been suggested that flooded underground workings could also be the cause of such data. However, there is no record of underground workings in the vicinity of lines 700 and 750 west (Boyle, 1972).

On line 50 east, another in-phase crossover is noted at station 55, as well as on line 200 east at staion 65. In these cases, quadrature data on both lines follow a pattern for the in-phase response, although there are differences in the dip angles for the quadrature data. In the case of line 50 east, for example, the quadrature data indicate a positive crossover at station 10 north. This is indicative of a buried conductor (Geonics, 1980). The lower dip angles for quadrature response on lines 50 and 200 east are indicative of swampy ground along those lines. This is certainly the case on both of these lines, which run through low-lying ground around Rainy Cove Brook.

In the vicinity south of the Walton mine an excellent crossover, believed to represent a mineralized Macumber Formation signature, was obtained in the vicinity of line 700 west. This strong quadrature crossover at station 75 south represents the best example

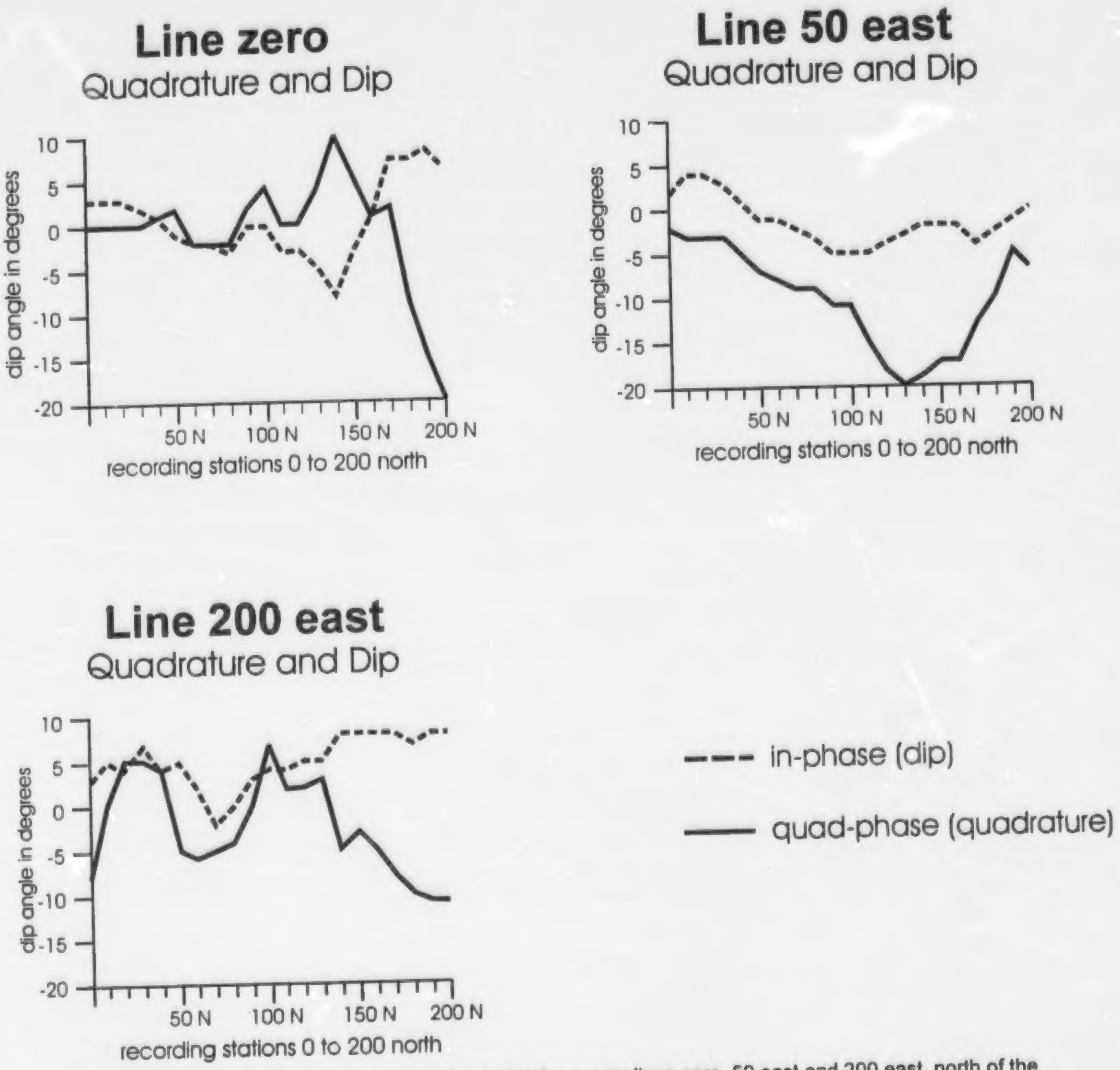


Figure 2. Graphs of in-phase and quad-phase dip angles for survey lines zero, 50 east and 200 east, north of the Walton open pit.

of a Macumber Formation signature in this survey. The strength of the crossover is probably due to the line traversing a steeply dipping, tabular sulphide body in the vicinity of the shaft and oriented at right angles to the survey line. Line 750 west also shows a strong in-phase response for two conductors at stations 30 and 110 south. Quadrature data on these lines exhibit consistently lower angles than the in-phase data. This can also be attributed to drainage patterns in the area. Both lines in this vicinity cross a small drainage valley between stations zero and 100 south.

At the Three Kilometer showing, tie line 1000 has a complicated VLF-EM signature. The in-phase data indicating two weak conductors at stations 925 and 1550 south are not reflected by similar data for the quadrature at these stations. This is indicative of surficial response only and may be caused by supergene enrichment of small fault planes similar to those observed in the aggregate quarry that exposed the Three Kilometer showing. Tie line 1380 also reveals a complicated pattern. However, there is a crossover noted at the southern extremity of the line, near station 1950 south,

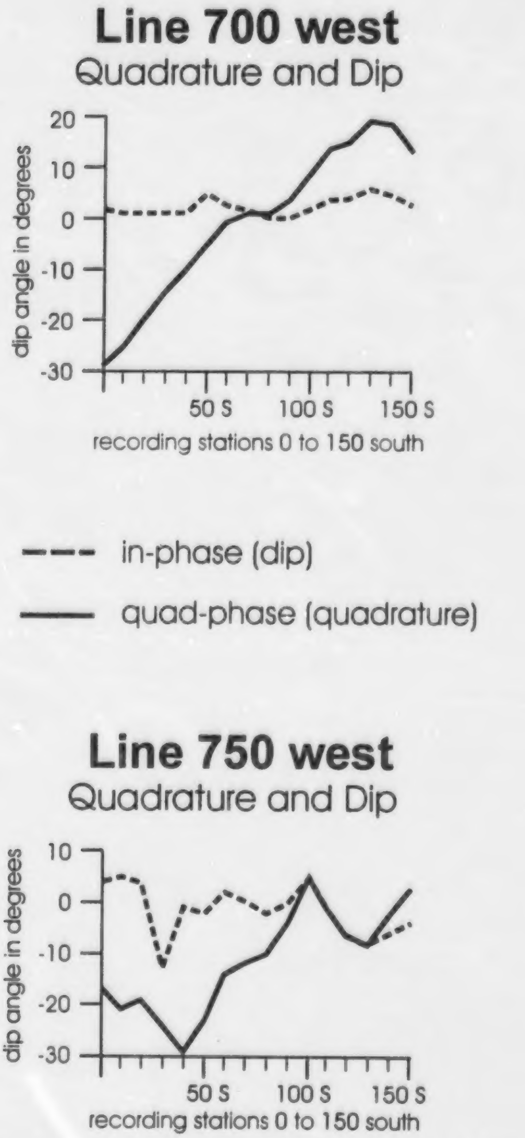


Figure 3. Graphs of in-phase and quad-phase dip angles for survey lines 700 west and 750 west, south of the Walton open pit.

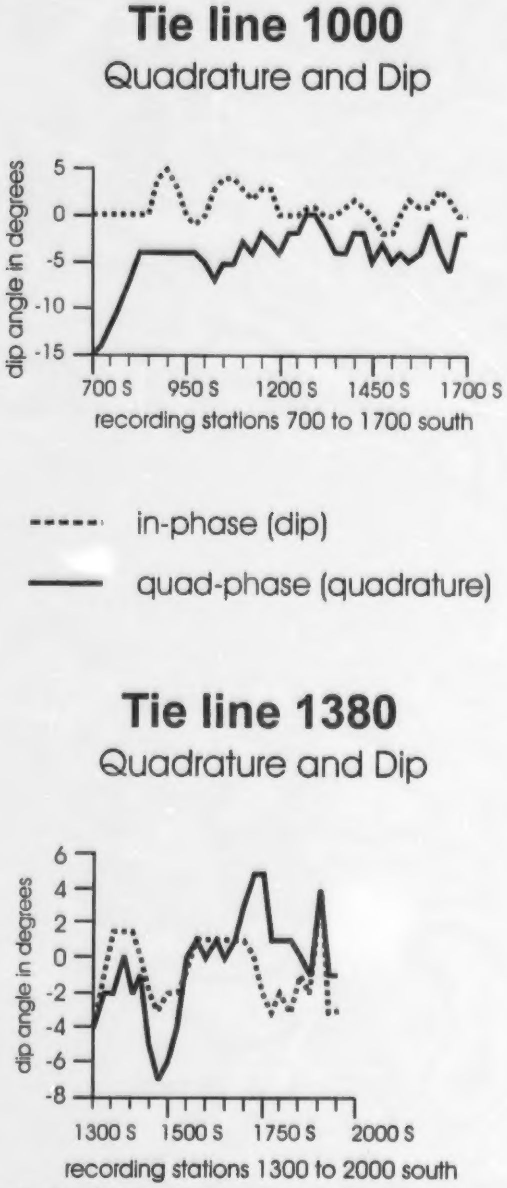


Figure 4. Graphs of in-phase and quad-phase dip angles for survey lines 1000 and 1380, north of the Three Kilometre showing.

where both the quadrature and in-phase dip angles display a positive crossover. This may reflect buried Macumber Formation rocks. The Macumber Formation has been noted in the vicinity of Wade Lake (Black, 1984). This is (roughly) along strike with this crossover, considering the high degree of fracturing in the area. However, conductors are relatively weak on both tie lines, and probably reflect either low-grade mineralization or deeply buried conductors. The long, flat negative quadrature crossover for tie line 1380 between stations 1550 and 1700 south is probably indicative of sulphide enrichment in a flat-lying body, or minor enrichment, over the length of the section.

Conclusions

This pilot study was successful in illustrating a VLF-EM signature for the Macumber Formation in the vicinity of the Walton mine site. Data will be compared to other work in the area when targeting potential drill sites. The survey will be augmented with data from a proton magnetometer and resistivity survey in future, to see if relationships exist between the VLF-EM signature and other geophysical surveys. This will provide investigators with a simple model for ground geophysical work, with the most common instruments used in prospecting, which can be used when exploring for Walton-type mineralization in the Macumber Formation of Hants County.

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Stratigraphy, Sedimentology and Depositional History of the McBean Seam Interval in the Pictou Coalfield, Stellarton Basin

R. D. Naylor, K. Giles and C. Kennedy

Introduction

The Stellarton Basin is located in central mainland Nova Scotia (Fig. 1). The basin is home to the Pictou Coalfield (NTS 11E/10) where coal mining has been carried out intermittently since 1818. Concurrent with mining has been the search for additional coal resources. Beginning in the early 1900s drilling formed a key element of many of the coal exploration efforts within

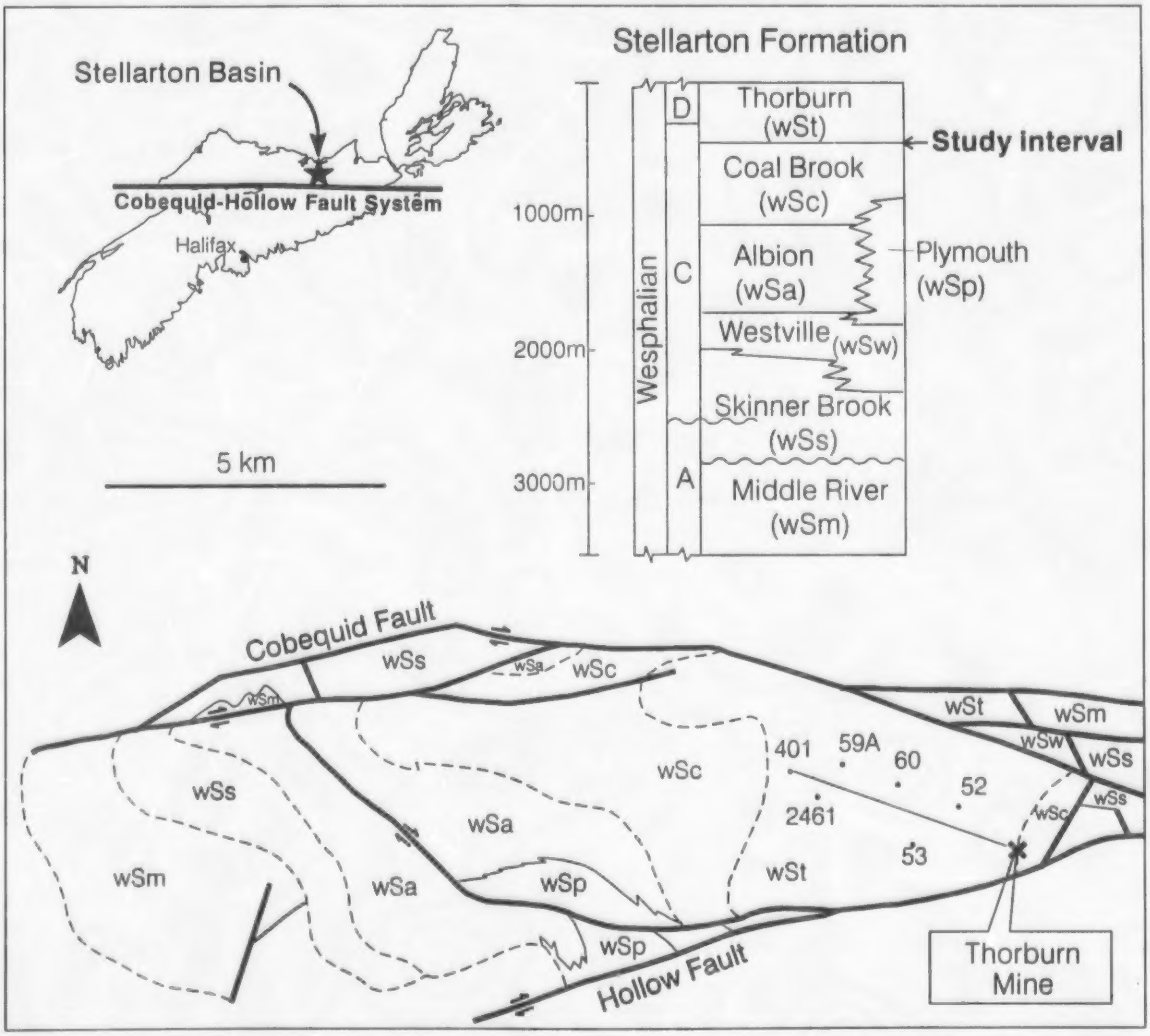

Figure 1. Geological sketch map of the Stellarton Basin indicating member boundaries of the Stellarton Formation, the location of the Thorburn Mine site and the drillholes that were used as part of this study. Also illustrated is a stratigraphic column of the Stellarton Formation showing member sub-divisions.

the basin. This has resulted in over 400 holes being drilled to date. Written records are available for most of the holes and cores are available for many of the holes drilled after 1970. Drilling data have provided an important basis for much of the stratigraphic correlation within the basin. In contrast, less attention has been given to detailed examination of surface exposures.

During the last five years a number of new surface coal mines have opened in the Stellarton Basin. Strata exposed in the highwalls of these mines provide an excellent source of new information on a number of important stratigraphic intervals. The research carried out as part of this project focuses on the McBean Seam and the initial 30 m of strata overlying it. Data were collected from drill cores and from the highwall of the Thorburn Surface Mine (Fig. 1). The purpose of this research is to better understand the stratigraphy, sedimentology and depositional history of the study interval.

General Geology

The Stellarton Basin is a 120 km^2 pull-apart basin that formed during the early Westphalian, at a releasing bend of the Cobequid - Hollow Fault System (Fig. 1). Infilling of the basin began during the Westphalian A and continued until at least the Westphalian D. The basin fill has been assigned to the Stellarton Formation (Fig. 1) and comprises mostly grey mudrock and sandstone interbedded with oil shale and coal. The basin contains 60 oil shale beds and 26 coal seams, including the 14 m thick Foord seam which is the thickest coal seam in eastern Canada.

Rapid coarsening and reddening of strata near the current fault-bounded limits of the basin in the east and southeast indicate that in these areas the paleo-depositional margins are probably close at hand. Elsewhere the depositional limits of the basin are more difficult to determine.

Naylor *et al.* (1989, 1992) interpreted most of the basin fill to consist of lacustrine, lacustrine delta and mire deposits. Lake formation was attributed to rapid basin floor subsidence accompanied by a decrease in sediment supply from regionally sourced rivers. This resulted in the periodic formation of a lake that would cover much of the basin floor. Mires are interpreted to have developed when lacustrine deltas infilled a lake and plants colonized the emergent delta plain. When a lake was completely infilled a mire would develop over large areas of the basin. In contrast, partial infilling of a lake only provided a stable substrate for peat formation closer to basin margins.

Stacked alluvial fan sequences adjacent to basin margins interfinger abruptly basinward with coal, lacustrine and lacustrine delta deposits. Higher basin margin relief is interpreted to be responsible for the development of redbeds and paleosols.

Stratigraphy of the Study Interval

The study interval is located at the base of the Thorburn Member approximately 500 m stratigraphically below the top of the Stellarton Formation (Fig. 1). The interval is 21 to 32 m thick and includes all the strata from the base of the McBean Seam to the top of oil shale #12 (Fig. 2). Our research efforts were confined to the east side of the Stellarton Basin (Fig. 1) where the study interval is much better preserved.

Figure 2 illustrates a southwest to northeast stratigraphic section of the study interval from the Thorburn Surface Mine to drillhole 401 (Fig. 1). The section is approximately 5 km in length and was constructed using existing drill records and new data gathered for this study from the Thorburn Surface Mine and drillholes P59a and 401.

The stratigraphic section illustrates a gradual basinward thinning and pinching out of the McBean Seam accompanied by a gradual thickening of oil shale #13. Mining records from former underground operations on the McBean Seam also clearly indicate a gradual thinning of the seam basinward. The maximum thickness of the McBean Seam is approximately 2.3 m.

Strata between oil shale #12 and #13 consist of grey and minor red mudrock and pale grey fine- to medium-grained sandstone. At the Thorburn Mine, 27 m of strata separate the two oil shales. In contrast, the two oil shale units in drillhole 401 are only 11 m apart. Thinning of the interval basinward is accompanied by a rapid increase in the ratio of mudrock to sandstone. The fine- to medium-grained sandstone, which is common at the Thorburn Mine site, pinches out completely by drillhole P59A.

The uppermost unit of the study interval is oil shale #12. Unlike oil shale #13 this oil shale unit has no coal associated with it. However, oil shale #12 also thickens significantly basinward from 2 m at the Thorburn Surface Mine to approximately 5 m in drillhole 401.

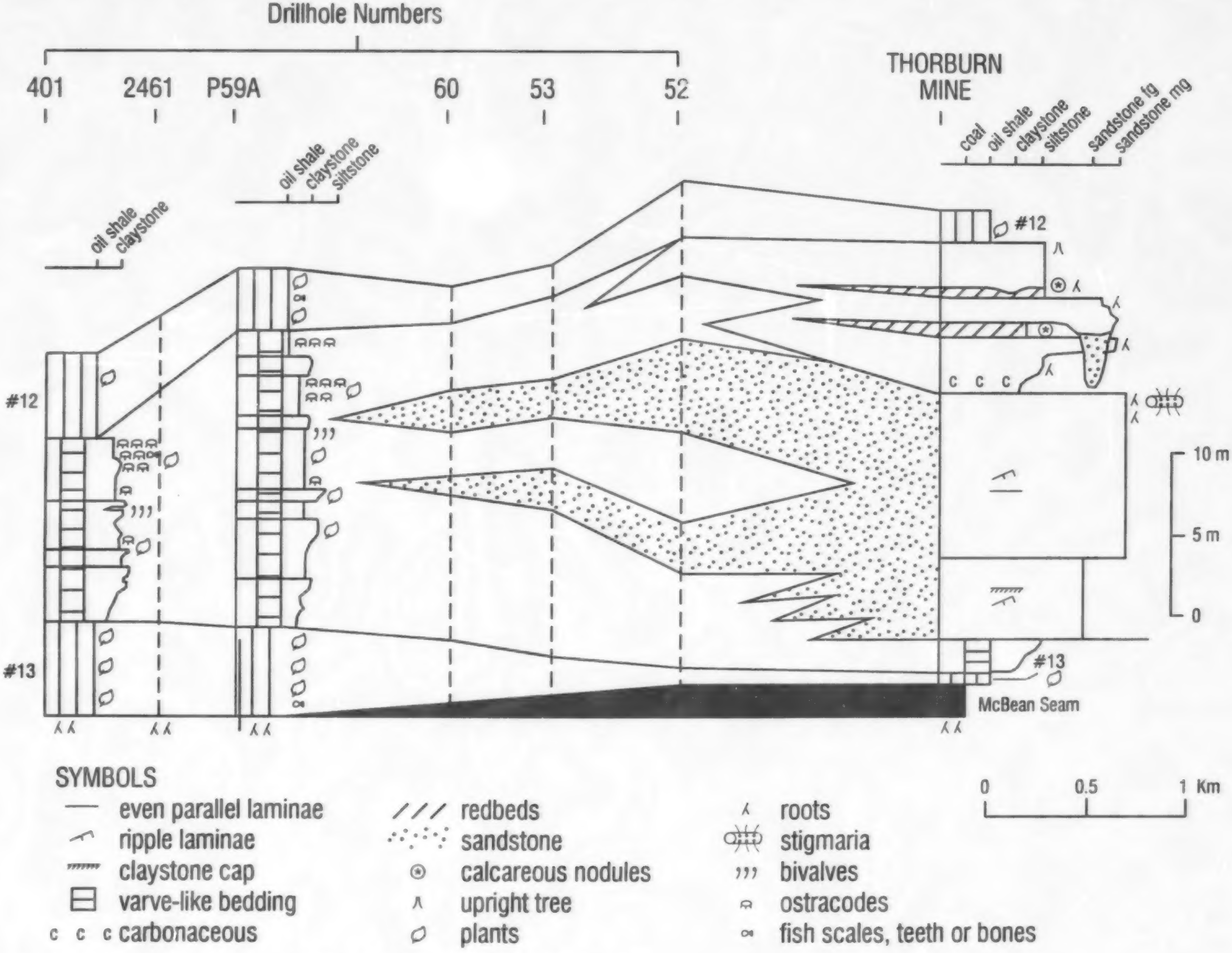

Figure 2. Stratigraphic cross-section of the study interval (see Fig. 1 for location).

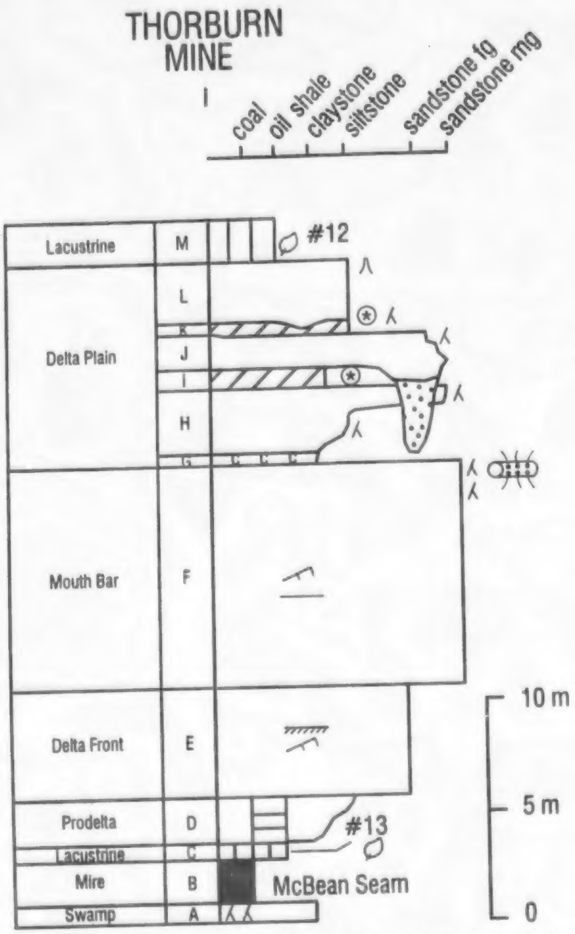

Figure 3. Measured section from the Thorburn Mine site indicating the position of Units A to M and the interpreted environments of deposition.

Sedimentology of the Study Interval

The sedimentology of the study interval was examined at the Thorburn Mine and in continuous cores from drillholes P59a and 401. Lateral changes in seam thickness and facies architecture were examined at the Thorburn Mine site.

Thorburn Mine Section

Figure 3 illustrates a 34 m measured section from the highwall of the Thorburn Mine. The section was constructed from measurements made near the northernmost limit of the mine. For the purposes of this report we have subdivided the section into 14 units that have been lettered A through M (Fig. 3).

Unit A, at the base of the section, consists of a grey-brown silty underclay which is overlain by 0.10 m of dark grey to black claystone. The underclay is extensively disrupted by roots and the dark grey to black claystone contains abundant, poorly preserved plant remains.

Unit B is the McBean Seam which has a dull microbanded appearance and an average thickness of approximately 2 m.

The McBean seam is overlain by oil shale #13 (Unit C) which consists of 0.80 m of dark grey to black oil shale containing siderite layers (3 cm max.) and fossilized plants (lepidophylloides, cordaites and seeds). Both the McBean Seam and oil shale #13 can exhibit rapid lateral changes in thickness. Near the location of the measured section the McBean Seam becomes reduced in thickness by 0.42 m over a distance of only 12.5 m. The abrupt lateral thinning of the McBean Seam is accompanied by a corresponding increase in the thickness of oil shale #13.

Oil shale #13 is gradationally overlain by Unit D, a 5.50 m interval of grey, rhythmically layered mudrock with thin (<15 cm) interbeds of pale grey fine-grained sandstone. The rythmically layered mudrock has distinct varve-like laminae that are 1 mm to 1.5 cm thick. Each varve couplet consists of a grey silty lamina overlain by a dark grey clay- rich lamina. The thin sandstone interbeds that constitute approximately 30% of Unit D increase in abundance and thickness up section. A typical sandstone bed fines upward and exhibits carbonaceous even-parallel or ripple laminae. The base of a sandstone bed is usually planar and non-erosive. However, some beds locally erode up to 5 cm into rhythmically layered mudrock. Siderite layers are common throughout Unit D.

Unit E is 5 m thick and also consists of pale grey fine-grained sandstone and rhythmically layered mudrock. However, sandstone makes up approximately 70% of this unit. Individual sandstone beds typically fine upward and are often capped by a claystone layer that is <1 mm thick. Sandstone beds usually appear tabular but locally they exhibit gently erosional bases. Even-parallel and ripple laminae are common and siderite intraformational clasts were noted locally.

Unit F consists of 10 m of thickly bedded (0.5 to 1.5 m), pale grey, fine- to medium-grained sandstone with rare thin (1 to 2 cm) interbeds of grey claystone. The thickness of the sandstone beds increases up section. Lower in the interval sandstone beds commonly exhibit climbing-ripple laminae. Higher in the section beds appear massive or contain faint, even-parallel laminae. Thicker beds can be low angle cross-stratified and locally have low angle erosional bases that cut up to 1 m into the underlying strata. Millimetre-scale claystone layers cap many of the sandstone beds. A distinctive 20 cm interval of convolute bedding was noted 6.80 m from the base of Unit F. This convolute interval is traceable over large areas of the mine site. Intraformational clasts (grey mudstone and siderite) are locally developed at the base of sandstone beds. Coalified, transported fossil trees were also noted locally. The upper 1.6 m of Unit F is extensively bioturbated by roots and contains well preserved fossil root stocks (stigmaria) and rootlets.

Unit G consists of 0.20 m of rooted, friable grey mudrock with local dark grey to black organic-rich layers up to 5 cm thick.

Unit H is a 3.35 m interval that coarsens upward from grey siltstone to thickly bedded fine- to medium-grained sandstone. The fine- to medium-grained sandstone was observed to grade laterally into siltstone. Siderite nodules and poorly preserved organic matter were observed within the siltstone. Roots are common throughout Unit H.

Unit I consists of approximately 0.50 m of red and green-grey mudrock with calcareous nodules.

Unit J typically consists of approximately 1.5 m of rooted grey siltstone and very fine-grained sandstone. However, a channel developed within Unit J locally cuts down at least 5.5 m to near the top of unit F (Fig. 3). Paleocurrent data and bedding orientation suggest that the same side of the channel is exposed twice. Therefore, the apparent view is of a channel bend, making it difficult to accurately calculate the total channel width and depth. The deepest parts of this channel are typically infilled by up to 1 m of pale grey medium-grained sandstone which contains local pebble-sized lithic clasts. The remainder of the channel fill is lithologically similar to Unit E, consisting of interbedded grey siltstone and pale grey fine-grained sandstone. Only the upper half of the channel fill is rooted.

Unit K is a 0.75 m thick, red and green-grey mudrock interval which contains local to common calcareous nodules.

Unit L is 2.85 m thick and consists of friable grey nodular siltstone with occasional pale grey fine-grained sandstone interbeds (<0.30 m) near the base. The upper 0.90 m of Unit L contains poorly preserved upright trees.

Unit M, the uppermost unit of the section, is oil shale #12. The contact between the oil shale bed and the underlying nodular siltstone is marked by a 0.20 m thick, dark grey fine-grained sandstone with abundant transported plant debris. Oil shale #12 is 1.93 m thick and very organic-rich over the lower 1 m.

Drillholes P59A and 401

In drillholes P59A and 401, the study interval lacks the diversity of facies seen at the Thorburn Mine. Due to the similar vertical arrangement of facies in each of the drillholes the two sections are described together.

In drillholes P59A and 401, the base of the study interval consists of pale grey fine-grained sandstone and siltstone containing abundant roots and local siderite nodules. This interval is correlative with Unit A from the Thorburn Mine section. Abruptly overlying this rooted interval is oil shale #13 (Unit C) which is approximately 5 m thick in both drillholes. Local plant fossils (cordaites, lepidostrobus and seeds) were noted throughout oil shale #13 in both cores. Fossil fish scales and bones were noted near the base of oil shale #13 in drillhole P59A.

The interval between oil shale #12 and #13 thins from 18 m in drillhole P59a to 11.5 m in drillhole 401. Grey rhythmically layered mudrock makes up 90% of the interval. Claystone is the dominant grain size. However, interbeds of siltstone up to 1 m thick were noted locally and siderite layers 0.2 to 2 cm thick are common. Crude coarsening upward cycles are developed at the 1-3 m scale between the two oil shales. In both drillholes 0.08 to 0.35 m interbeds of dark grey to black shale, transitional in character to oil shale, become common within 6 m of the base of oil shale #12. These organic-rich shales contain local plant fossils (cordaites, lepidophylloides, lepidostrobus) and local to abundant ostracodes. A bivalve (*anthracanauta* sp.) rich layer was noted approximately 4 m below oil shale #12 in both drill cores. Rare fish scales and teeth were observed in some organic-rich shales.

Oil shale #12 (Unit M) is 4 m thick in drillhole P59A and 5 m thick in drillhole 401. Plant fossils (cordaites and lepidostrobus) are rare to local within oil shale #12 in both drillholes.

Depositional Environments

Thorburn Mine Section

Figure 3 illustrates the general environment of deposition for each of the units described in the highwall of the Thorburn Mine. A discussion of the specific environment of deposition that has been interpreted for each unit is presented below.

The rooted underclay at the base of Unit A is interpreted to be a paleosol that developed below a forested swamp. Preservation of plant material in the carbonaceous claystone immediately above the underclay suggests that initially the swamp was poorly drained and not well aerated. The upward transition from carbonaceous claystone to coal (McBean Seam, Unit B) marks the development of peat-forming conditions and the change-over from a poorly drained swamp to a mire. Although the onset of peat formation coincides with a reduction in clastic input, the dull microbanded appearance of the McBean Seam suggests frequent, perhaps seasonal, flooding of the mire.

The development of oil shale #13 above the McBean Seam indicates that permanent flooding of the McBean mire ended peat accumulation. However, local thinning of the McBean Seam over very short distances indicates that initially only specific areas of the mire were drowned. Differential subsidence of the mire may have resulted in the local development of drainage channels and ponds. This in turn would have created a topography on the mire surface that was subsequently infilled by the organic-rich muds that were the precursors of oil shale #13. The absence of roots and paleosol features suggests the muds that formed oil shale #13 were never sub-aerially exposed.

The coarsening upward succession (units D, E, and F) deposited above oil shale #13 is interpreted to have been formed by a prograding lacustrine delta. The rhythmically layered mudrocks of Unit D are interpreted to be distal/prodelta deposits. Each varve-like layer contained within this facies may represent an annual depositional event. However, the formation of similar varve-like layers can be attributed to seasonal flood events which could produce more than one layer annually. The thin sandstone beds that constitute approximately 30% of Unit D are interpreted to represent delta front sands interfingering with the prodelta muds.

The sandstone-dominated facies that constitute Unit E are interpreted to be delta front deposits. Normal grading of sandstone beds is attributed to deceleration of flow strength when floodwaters entered the lake. The thin claystone layers that cap individual sandstone beds are interpreted to have formed from clay sized sediment that settled from suspension following a flood event.

Unit F is interpreted to consist of the most proximal of the permanently subaqueous lacustrine delta deposits. Collectively we have referred to these as mouthbar deposits. The common occurrence of climbing-ripple bedding lower in Unit F suggests large amounts of sandy sediment were introduced rapidly from suspension. This would be expected to occur when flood waters carried by a distributary channel initially enter a lake. The low-angle erosional surfaces that occur in the upper part of Unit F were probably formed by broad and shallow subaqueous distributary channels. Not surprisingly, lags formed from transported siderite clasts and plant material are often found in close association with these erosional surfaces. Thicker beds that contain low-angle cross stratification are interpreted as low relief bars that formed adjacent to and in front of subaqueous distributary channels.

Units G through L are interpreted to be delta plain deposits, in part based on the fact that they have been vegetated and subjected to soil-forming processes. The transition from subaqueous delta to delta plain is marked by Unit G. The abundant occurrence of fossil roots at the top of Unit F and within Unit G indicate that Unit G was forested. Therefore, the claystones of Unit G are interpreted to have been deposited in a swamp that formed on the emerging delta. Poor preservation of organic matter suggests the swamp was fairly well aerated.

The mudrocks and sandstones that comprise Unit H are broadly interpreted to have been deposited in the overbank areas of the delta plain. The grey colour, occurrence of siderite nodules, and preservation of organic matter suggest that the overbank areas were poorly drained. Disruption of bedding features by roots indicates that sedimentation rates were low enough to allow plant growth. Rapid lateral lithologic changes (e. g. sandstone to mudrock) indicate that the sandstone probably does not represent sheet flow deposits and, therefore, may have a levee or crevasse splay origin. The coarsening upward trend in Unit H may have been caused by progradation of a crevasse splay into the overbank area.

The transition from Unit H (grey beds with siderite nodules) to Unit I (redbeds with calcareous nodules) indicates that overbank areas became better drained and more mature plaeosols began to form. Improved drainage was probably caused by deeper incision of distributary channels into the delta plain. The sandstone- and mudrock-filled channel described in Unit J is a good candidate for a deeply incised distributary channel. Down-cutting of this channel may have occurred in response to a lowering of base level, caused by a drop in the lake level. Infilling of the channel would require a rise in base level, caused by either a rise in lake level or infilling of the lake with sediment. Rooted grey siltstones that overlie and are developed lateral to the channel are interpreted to be overbank deposits. The red mudrocks of Unit K are interpreted to have the same origin as those in Unit I.

The upward transition from the redbeds of Unit K to the grey mudrocks of Unit L suggests the return of more poorly drained conditions to this area of the delta plain. Unit L still exhibits abundant evidence of paleosol development, including the common occurrence of roots, calcrete nodules and pedogenic slickensides. The poorly preserved upright trees at the top of Unit L suggest that sedimentation rates were periodically relatively high. However, sedimentation rates were clearly low enough to allow for significant soil development. The uppermost unit of the measured section, oil shale #12 (Unit M), is interpreted to represent organic-rich lacustrine mud that was deposited when the sediment supply rate was low. The occurrence of oil shale #12 immediately above Unit L indicates that a significant rise in the water table eventually drowned the delta plain in this location.

Drillholes P59A and 401

Many of the units that were recognized in the Thorburn Mine section are absent in drillholes P59A and 401. However, some units (e.g. oil shales and Unit D) are thicker and contain additional fossils and sedimentary structures that provide further insights into the depositional environments.

The underclay at the base of the Thorburn Mine section was not observed in drillholes P59A and 401. Instead, Unit A consists of sandstone which appears similar to the rooted mouthbar deposits that comprise the top of Unit F in the Thorburn Mine section. However, it is important to note that approximately 400 m west of drillhole 401, on McLellans Brook, there is a well developed underclay immediately below oil shale #13.

Oil shale units 12 and 13 are once again interpreted to consist of organic-rich lacustrine mud. The occurrence of fish scales and bones in both oil shales indicates that lake waters were rich enough in nutrients and oxygen to support a fish population. The majority of organic material in Stellarton oil shales is highly degraded. Therefore, it is possible that the plant macro-fossils (e.g. Lepidostrobus, Cordaites) preserved within the oil shale beds were more resistant to decay.

The rhythmically layered mudrock unit that separates oil shale units 12 and 13 is interpreted to consist predominately of prodelta deposits. Thin, organic-rich layers within the mudrock appear to be gradational to oil shale and, therefore, may have been deposited when clastic supply to the lake was low. The occurrence of ostracode and bivalve fossils within these organic-rich layers indicates that bottom waters were rich enough in oxygen and nutrients to support a benthic fauna.

Depositonal History

The most complete record of sedimentation and peat accumulation in the study interval is preserved in the Thorburn Mine section. However, to understand the depositional history in more detail it is necessary to look at the possible temporal relationships among all three measured sections.

Pervasive rooting at the base of all the sections indicates deposition of the study interval began with widespread development of a forested swamp. This was apparently followed by re-establishment of lacustrine conditions in more central areas of the basin and development of a peat swamp east of drillhole P59A. Thickening of the McBean Seam toward the eastern end of the basin suggests that the McBean mire was gradually drowned when the central basin lake slowly transgressed eastward. It is possible to estimate the rate at which this transgression occurred by considering how quickly peat accumulated in the McBean mire. Approximately 5 mm of peat accumulates annually in modern tropical mires. An acceptable estimate of the compaction ratio of peat to coal is approximately 10:1. Assuming 5 mm of peat also accumulated annually in the McBean mire it would have taken approximately 4000 years to accumulate enough peat to form 2 m of coal. The McBean Seam is approximately 2 m thick at the Thorburn Mine site and pinches out completely near drilhole P59A. Therefore, the lake shoreline must have transgressed approximately 1 m per year to cover the 3 .75 km between drillhole P59A and the mine site.

It is difficult to be certain if oil shale #13 was deposited as the lake transgressed across the McBean mire. However, thickening of oil shale #13 coincides with thinning of the McBean Seam, suggesting that they may be coeval deposits. Although some of the organic material in the oil shales is undoubtably of algal origin, inter-swamp drainage channels would have carried significant amounts of plant material from the McBean mire to the lake. The clay component of the oil shale could have been supplied from sediment-rich streams that were entering the lake elsewhere in the basin.

Deposition of prodelta muds over oil shale #13 is interpreted to signal an increase in sediment supply to the lake. The coarsening upward succession at the Thorburn Mine site records the gradual progradation of a delta into the lake. However, basinward only prodelta muds were deposited and there is no obvious evidence of the delta progradation.

The abandoned channel developed within Unit J (Figs. 2 and 3) indicates that sediment continued to be transported to the lake even when redbeds and paleosols were developing on the delta plain. However, Figure 2 illustrates that, basinward, no major sandstone units appear to have been deposited contemporaneously with the delta plain deposits in the Thorburn Mine section. This suggests that as the delta plain extended farther into the basin, distributary channels were no longer capable of transporting significant amounts of sand sized sediment to the lake. Therefore, the overall sediment supply to the lake may have decreased as the delta plain developed more fully. Growth of the delta plain would have provided an ever-increasing area for plants to colonize. This in turn would probably have caused an increase in the supply of organic material to the lake. A decrease in sediment supply and an increase in organic nutrients entering the lake may have favoured an overall increase in faunal production. This may account for the dramatic increase in ostracodes, bivalve and fish fossils in the upper 5 to 7 m of the prodelta deposits (Fig. 2).

Development of calcareous paleosols on the delta plain indicates that the rate of vertical accretion of sediment was low. Therefore, the delta plain is interpreted to have gradually sunk below the lake surface due to the combined effects of tectonic- and compaction-related subsidence. Deposition of oil shale #12 immediately above the delta plain deposits indicates sediment supply remained very low. The absence of a coal seam below oil shale #12 may indicate that the delta plain subsided too rapidly to allow peat formation. However, the absence of coal could also indicate that although sediment supply was low, it may still have been too high to allow for peat formation. Other possible factors that could have deterred peat formation are climate and the nature of the plants that colonized the delta plain.

Conclusions

Lacustrine delta deposits in the Stellarton Basin can be broadly sub-divided into prodelta, delta front, mouth bar and delta plain deposits. Each of these lacustrine delta sub-environments comprises a characteristic suite of facies.

It appears that the coal and oil shale deposits of the Stellarton Basin may be coeval. However, further work is required to determine why most delta plain sequences are immediately overlain by oil shale as opposed to coal. Once this is better understood it may be possible to develop new models for coal exploration in the Stellarton Basin.

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The Lower Caledonia Beryl Pegmatite (NTS 11E/08), Guysborough County, Nova Scotia

G. A. O'Reilly

Introduction

A beryl-bearing pegmatite was discovered during a Mineral Inventory Project field check of the Lower Caledonia Au-Pb-Zn prospect (NTS 11E/08), Guysborough County, in July 1999. The prospect and pegmatite occur 5 km west of the small community of Lower Caledonia along the road following West River St. Marys toward Caledonia (Fig. 1). The pegmatite had been noted during previous exploration of the prospect, but the presence of beryl was not previously recognized.

Geological Setting

The West River St. Marys follows the West River St. Marys Fault, the southernmost suture of the east-west Cobequid-Chedabucto Fault System which subtends mainland Nova Scotia from Canso to Cape Chignecto. At Lower Caledonia this fault marks the southern boundary of the St. Marys Graben. The graben consists of Carboniferous clastic sedimentary rocks of the Horton Group, and is in contact with Cambro-Ordovician Meguma Group metasedimentary rocks which underlie much of the area to the south (Fig. 1). These rocks belong to the Goldenville Formation, the lower of two formations that constitute the Meguma Group. Intense ductile and brittle deformation related to movements along the fault have affected rocks on both sides of its trace.

In the Lower Caledonia area, the metasedimentary rocks form a scarp along the graben and consist of an interbedded sequence of metawacke, metasiltstone and minor slate. The scarp is intruded by numerous elongate plutons and dykes of foliated two-mica

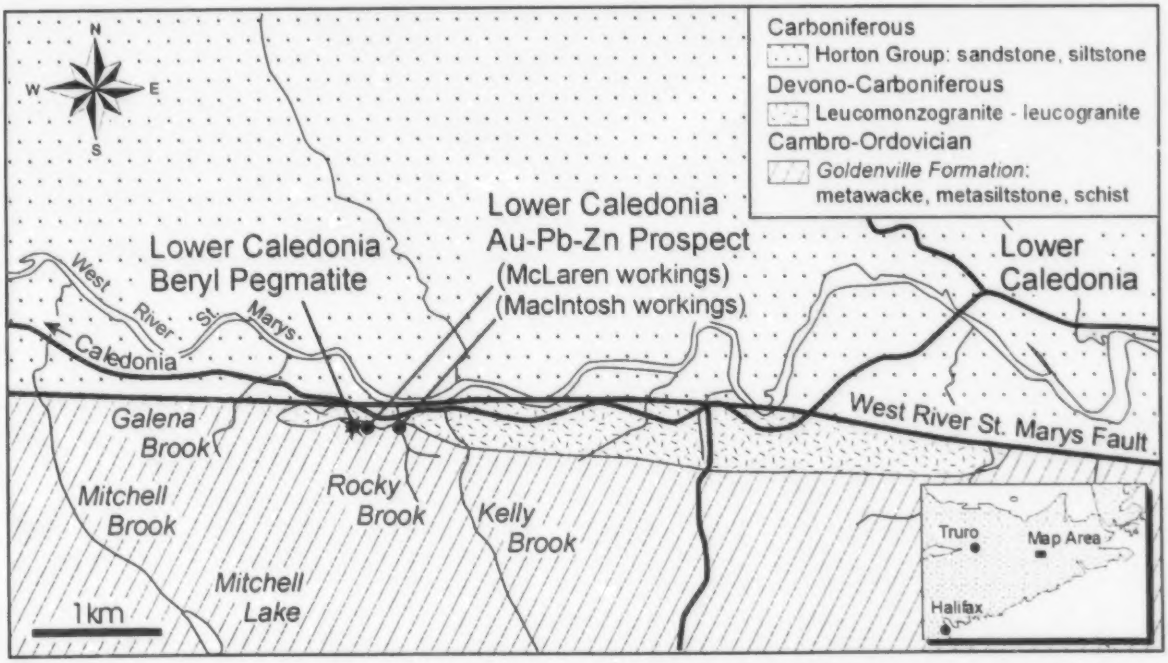
N
W
E
S
Carboniferous
Horton Group: sandstone, siltstone
Devono-Carboniferous
Leucomonzogranite - leucogranite
Cambro-Ordovician
Goldenville Formation: metawacke, metasiltstone, schist
Lower Caledonia Au-Pb-Zn Prospect (McLaren workings) (MacIntosh workings)
Lower Caledonia Beryl Pegmatite
Lower Caledonia
West River St. Marys
Caledonia
West River St. Marys Fault
Galena Brook
Mitchell Brook
Rocky Brook
Kelly Brook
Mitchell Lake
1km
Truro
Map Area
Halifax

Figure 1. Geology of the Lower Caledonia area, Guysborough County, showing the location of gold and base metal occurrences and the beryl-bearing pegmatite.

leucomonzogranite of Devono-Carboniferous age (Faribault, 1886, p. 142). One of these elongate granitic plutons is found at Lower Caledonia (Fig. 1). Geological mapping and diamond-drilling, part of the previous mineral exploration efforts at the Lower Caledonia prospect, have shown that the mineralized quartz veins intrude highly deformed and hydrothermally altered metasediments in the exo-contact zone of this pluton. Although the relationship between gold-bearing veins and granite is somewhat unclear, there is little doubt that the beryllium-bearing pegmatite is genetically related to granite.

Exploration History

Gold Exploration

The year of discovery of the gold-bearing quartz veins at Lower Caledonia is not known for certain, but the first report of exploration work dates to 1937 (Goudge, 1937). By that time a 5 m deep shaft had been sunk and considerable trenching had been done at one site (McLaren workings on Fig. 1), and substantial trenching was in progress at a second site high on the west bank of Rocky Brook (MacIntosh workings on Fig. 1). Several references (cited below) following these 1937 reports refer to the MacIntosh workings as including a short adit that over the years has collapsed. Whether or not there actually was an adit cannot be confirmed.

The targets of these early exploration efforts were several highly deformed, auriferous quartz veins that intrude schistose and highly altered Goldenville Formation metasediments. Goudge (1937) indicated that the north trench at the McLaren workings exposed a "*10" roll of quartz*" and several other east-trending quartz veins that total 10 cm in width. These veins reportedly returned assay results of $13.00/ton. Several other leads were exposed in the trenched and cleared area surrounding the shaft (Fig. 1). The MacIntosh workings consisted of an 18 m long trench that exposed a 17 cm thick vein trending east and shallowly dipping to the southwest. Later in 1937, a trench some 6 m long, 4.5 m wide and 4 m deep was dug in the west bank of Rocky Brook. It is possible that shortly after that time this trench was deepened and extended as an adit.

In a memo appended to the collection of miscellaneous memos that constitute the Goudge (1937) reference, the Provincial Mines Inspector R. I. Grant reported in 1946 that considerable bulldozer trenching had been done at the McLaren workings and several flat-lying quartz veins were exposed. In a similar visit in 1952, Mr. Grant reported that "*free Au occurred in highly contorted quartz in schisted slate*". He also noted the presence of pyrite, chalcopyrite, pyrrhotite, sphalerite and galena in the veins. This is the first mention of base metal mineralization. McDonough (1953), working for Hemany Mines Limited, reported gold assays of 0.243, 0.91, 0.6, 0.28 and 0.243 oz./ton for chip samples collected over intervals of between 6 and 18 m from several of the trenches at both the McLaren and MacIntosh workings. In addition, a sample of 290 pounds was submitted to the federal government Mines Branch for treatment tests (see Appendix to McMullin, 1976). The tests returned a head grade of 0.26 oz. Au/ton and 0.37 oz./ton by screen analysis. Despite these encouraging results, Hemany did not continue exploration.

Base Metal Exploration

Interest in the base metal potential of the prospect did not commence until after release of the results of a stream sediment sampling survey carried out by the Geological Survey of Canada throughout northern Nova Scotia (Geological Survey of Canada, 1959). This survey showed a cluster of geochemical Pb anomalies in streams draining north from the Meguma Group basement into the West St. Marys River in the area between Caledonia and Glenelg. These results spurred Jonmar Syndicate to carry out follow-up soil geochemical, IP, resistivity and magnetometer surveys in the early 1960s (Meagher, 1966). Several areas of anomalous Pb and Zn were defined, as well as some geophysical targets. Trenching and one diamond-drill hole resulted in discovery of several base metal occurrences (Fig. 1). Trenching at two sites, one along what became known as Galena Brook about 1 km west of the gold prospect and another along the West River St. Marys near the mouth of Rocky Brook, exposed fault- and fracture-controlled Zn (0.3-1%), Pb (trace - 0.1%) and Ba (0.05-0.07%). At a third site, one diamond-drill hole was drilled to a depth of 60 ft. before being abandoned due to drilling problems and poor core recovery (15%). The hole was collared in an apparent fault or breccia zone and consisted mostly of broken metasediment to a depth of 59 ft., after which altered pegmatite was intersected for the remaining foot of the hole. Meagher (1966) reported that galena and carbonate coat the fracture surfaces on approximately half the metasediment fragments recovered, and traces of sphalerite and pyrite occur within the pegmatite.

Promising results from the Jonmar exploration and indications of base metal mineralization throughout this region found by the concurrent Nova Scotia Department of Mines St. Marys River Basin Project (including diamond-drill intersections of galena), led A. C. A.

Howe International Limited to acquire the ground and explore the Lower Caledonia prospect (Armstrong, 1969). This exploration effort was the first to note the presence of the large pegmatite dyke at Lower Caledonia. One of their three diamond-drill holes (DDH 69-1) was intended to test the relationship between the pegmatite and gold-bearing veins at the McLaren workings (Fig. 2). The drillhole proved the mixed pegmatite/granite dyke is still of substantial thickness between the easternmost of the pegmatite outcrops and the trenches of the McLaren workings (Fig. 2) but failed to shed much light on the relationship between the two. A second drillhole (DDH 69-2 on Fig. 2) was intended to test for pegmatite extension below and east of the shaft. This drillhole intersected mixed metawacke and schist and several quartz veins before passing into granite at 112 ft.* No gold was noted in the veins but "*smears of steel galena*" were common on fractures in the metasediment. The third drillhole at the MacIntosh workings quickly intersected granite and was abandoned. Armstrong (1969) concluded from the drilling that the entire area is underlain at shallow depth by granite and that this severely limits the tonnage potential of any mineral occurrence found in the metasediments. As a result the ground was dropped. He did not consider that base metals may be hosted by the granite.

The Armstrong (1969) report includes a map showing an area of "*Au in drift*" extending from the pegmatite dyke and McLaren workings and continuing farther to the east almost to Rocky Brook. The map also indicates the notation "*Au-Te found in place*" along the west bank of Rocky Brook, roughly corresponding with the MacIntosh workings. As interesting as these notations are, there is no further mention of them provided in the report.

McMullin (1976) carried out exploration of the site on behalf of Great Horn Mining Syndicate Inc. between 1972 and 1976. This effort focused on the gold and base metal potential of the site due to the increasing value of gold in the mid-1970s. Further geochemical surveys and a re-analysis of previous geophysical data indicated several strong exploration targets. One of these was tested with diamond-drill hole DDH 3-1 (Fig. 2) which was collared along the access road immediately southwest of the westernmost pegmatite outcrop and was drilled due south inclined at 45°. The drill log (McMullin, 1976) indicates that the hole intersected metasediment to a depth of 114 ft. then passed into mixed intervals of pegmatite, granite and metasediment to the end of the hole at 341 ft. No mineralization of any sort is indicated in the drill log, although it shows that at least one other pegmatite dyke of significant dimension occurs on the property.

In 1977 a second diamond-drill hole was drilled north from a site located approximately 100 m south of the McLaren workings to test an IP geophysical anomaly centered in that area (DDH 3-2 on Fig. 2; McMullin, unpublished data). The drillhole intersected highly contorted, garnetiferous schist and metawacke to a depth of 100.6 m below which a mixed sequence of schist, pegmatite and leucogranite were encountered to the bottom of the hole at 106.4 m. Minor to trace amounts of fracture-controlled galena and sphalerite occurred in the schist throughout the hole. The highest assay result was 0.15% Pb and 0.33% Zn. There is no mention of mineralized zones in the pegmatite and leucogranite.

Description of the Pegmatite

The beryl-bearing pegmatite dyke strikes 114° and has a strike length of at least 125 m as defined by the three outcrops and DDH 69-1 (Fig. 2). The width varies from 14-20 m at its east end to 2 m at its west end. The western outcrop is small and entirely pegmatite, so the possibility remains that the dyke is actually wider in that area but covered by till. In any event, it does appear as if the dyke narrows toward the west.

The East Outcrop

The easternmost pegmatite outcrop has a rounded, typically glaciated form, approximately 20 m long by 8-10 m wide (Fig. 3). The outcrop is predominantly pegmatitic, but does include gradational patches of leucogranite, especially along its northern margin and west-central portion of the outcrop. In addition, there are several enclaves of highly deformed schist incorporated within the dyke. The deformation is irregular, with patches exhibiting a well developed planar fabric, indicating intense localized ductile deformation, intermixed with what appears to be massive, undeformed pegmatite. However, on close examination, the widespread presence of minute layering within individual clear quartz crystals in the pegmatite is an indication of deformation on a microscopic scale. In all likelihood, each layer represents a separate micro-shear plane. A similar phenomenon is displayed within highly sheared quartz at the Jordan Falls Be pegmatite (Mineral Occurrence #P14-001) north of Shelburne in southwest Nova Scotia (Corey, 1994).

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*Cores that were logged in feet are cited in feet and not converted to SI units.

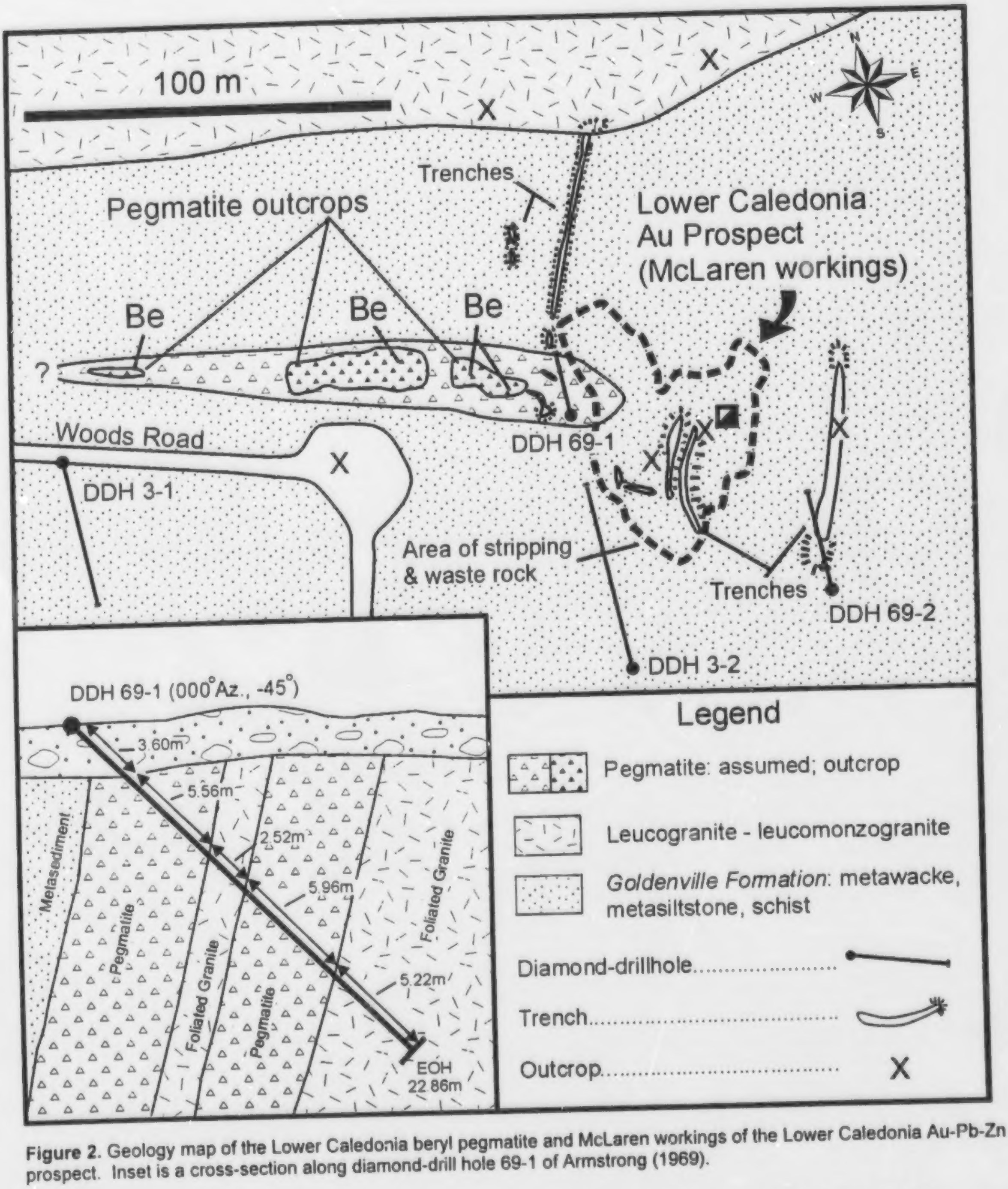

Figure 2. Geology map of the Lower Caledonia beryl pegmatite and McLaren workings of the Lower Caledonia Au-Pb-Zn prospect. Inset is a cross-section along diamond-drill hole 69-1 of Armstrong (1969).

The pegmatite is irregularly zoned. In general, there is a margin of coarse-grained quartz-K-feldspar-muscovite pegmatite which, in places, resembles a very megacrystic, highly evolved granite. The center or core portion of the outcrop is more K-feldspar-rich and consists predominantly of a mix of quartz and K-feldspar or, in some areas, essentially totally K-feldspar. Tourmaline occurs as fine- to medium-grained, euhedral, black crystals predominantly concentrated in the marginal zone of the pegmatite. Tourmaline is

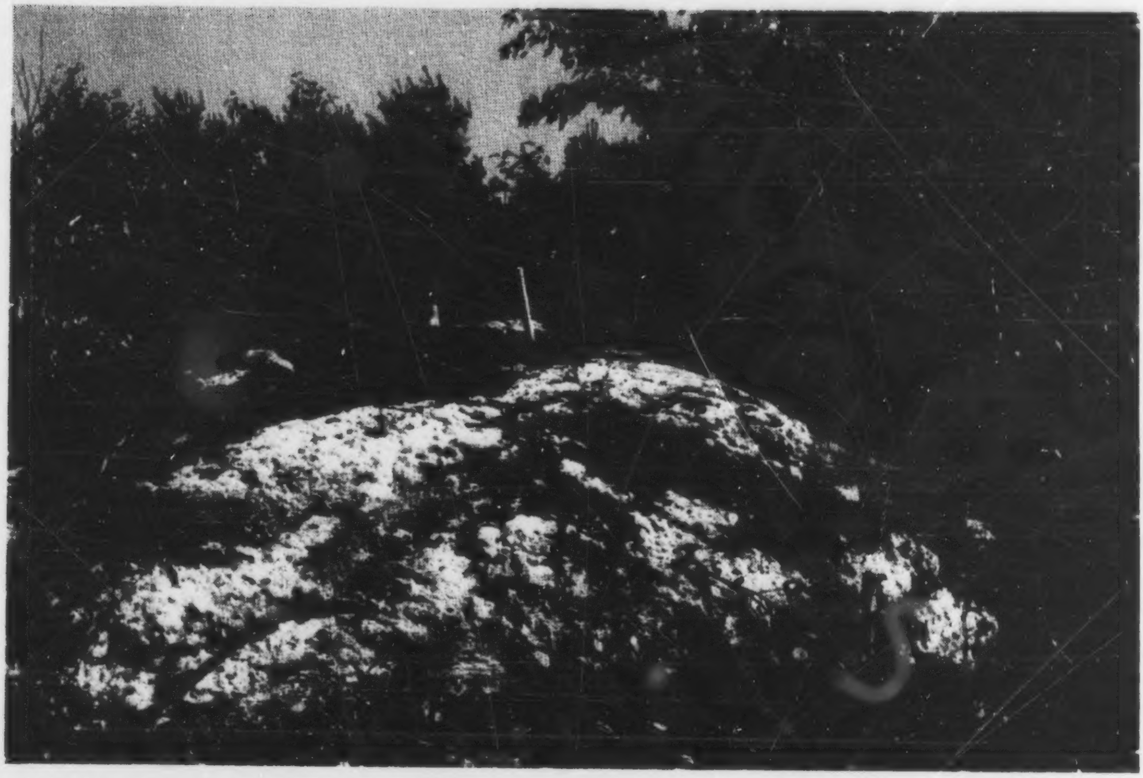

Figure 3. Photograph of the southwest face of the east outcrop of the Lower Caledonia beryl pegmatite. Much of the outcrop face below the hammer is beryl-rich.

especially concentrated adjacent to the schistose country rock or surrounding schist enclaves. There are a couple of patches of massive, fine-grained tourmaline and the black mineral imparts a dark colour such that these patches are easily mistaken for schist. Armstrong (1969) reported that garnet occurs in the pegmatite intersections in his diamond-drill holes, but garnet was not noted in any of the outcrops during the current study.

The east outcrop contains the highest concentration of beryl. A large portion of the central to southwest end of the outcrop reaches a very impressive 30-40 modal % of the mineral and is likely the richest Be occurrence known in the province. The beryl occurs as coarse euhedral to subhedral crystals (Fig. 4), generally with a cream to yellowish-cream colour. Several crystals are in the order of 4-6 cm in diameter. Beryl also occurs with tourmaline in two flat-lying to shallow-dipping quartz veins that intrude the pegmatite along the southeast end of the outcrop. The veins are between a few centimeters to 25 cm thick and the beryl occurs predominantly along the vein margin, although a few also occur within the veins themselves.

Armstrong (1969) drilled a hole (DDH 69-1 in Fig. 2) to examine the relationship of the pegmatite with the gold- and base metal-bearing quartz veins at the McLaren workings. The inset in Figure 2 shows this drill section and it is clear from it that the mixed pegmatite/leucogranite dyke underlies essentially all of that area. Armstrong makes no note of beryl occurring in either the drill core or in the pegmatite outcrops. Unfortunately, the drill core has long since been dumped.

The Middle Outcrop

The middle outcrop, largest of the three pegmatite exposures, takes the form of a rounded roche moutonée approximately 35-40 m long and 8-12 m wide. Much of the outcrop is well developed pegmatite, although, like the east outcrop, gradational leucogranite lenses occur. Schist enclaves are also present. The outcrop is irregularly zoned with a border facies of quartz - K-feldspar ± muscovite pegmatite grading into a central core of very coarse-grained K-feldspar ± quartz

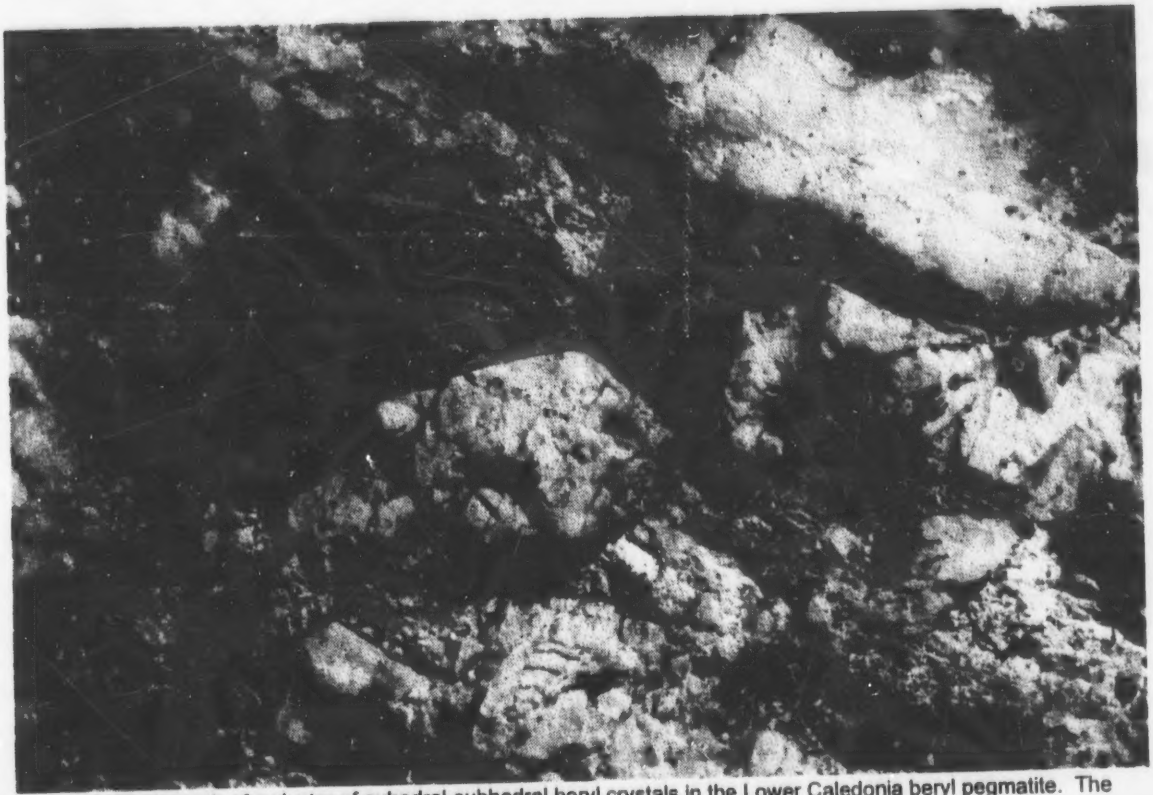

Figure 4. Photograph of a cluster of euhedral-subhedral beryl crystals in the Lower Caledonia beryl pegmatite. The large euhedral (hexagonal) crystal in the center of the photo is 5 cm in diameter.

pegmatite. The northern margin of the outcrop has a pronounced steep face dropping some 5 m down into a swampy area. The face is moss covered, but pegmatite was found underneath in several locations examined in the field check. It is not known how far under the swamp the pegmatite dyke extends toward the north.

A few beryl crystals were noted in the middle outcrop but there were no rich concentrations as exposed in the east outcrop. Euhedral, black tourmaline crystals also occur sporadically as do rare patches of massive, fine-grained tourmaline.

The West Outcrop

The westernmost outcrop is the smallest of the three at about 10 m long, 1-2 m wide and 1 m high. The southern margin of the outcrop appears to be in contact with schist country rock but the north contact is obscured due to till cover along the northern margin, so the true width of the pegmatite is uncertain. Most of the outcrop consists of an assemblage of K-feldspar - quartz - muscovite with lenses of leucogranite intermixed. The outcrop displays evidence of ductile deformation, particularly in the lenses of leucogranite which display a well developed planar fabric. Although the leucogranite appears to be more deformed than the pegmatite, it is important to note that in this outcrop the planar fabric continues outward from the leucogranite and into the pegmatite along discrete shear zones.

A few beryl crystals were noted in the central portion of the outcrop near its eastern end. In addition, a few fragmented and boudinaged beryl crystals were noted within a well foliated section along the north edge of the outcrop about half way along its length.

Other Pegmatites

A few other occurrences of pegmatite were noted in the exploration assessment files for Lower Caledonia. McMullin (1976) drilled a diamond-drill hole along the woods road immediately south and a few metres west of the westernmost pegmatite outcrop (Fig. 2). Core from this hole has since been dumped, but the log provided by McMullin (1976) indicates it intersected a 60 m thick mixed sequence of highly deformed schist, pegmatite and granite. This hole was collared to the south of the exposed pegmatite dyke and was drilled toward the south (i.e. away from the outcropping dyke). This indicates that a second, possibly en echelon, pegmatite dyke (or more than one) underlies the area south of the exposed pegmatite. Whether this second dyke is beryl-bearing is not known.

Meagher (1966) reported pegmatite dykes in three separate areas during the Jonmar Syndicate exploration of the site. Along the south bank of the West River St. Marys, immediately east of the mouth of Rocky Brook, an exploration trench exposed a major east-trending fault zone in which the goudge/breccia is intruded by a small pegmatite dyke. Galena, sphalerite and pyrite smears on the fracture surfaces of breccia fragments are common and the goudge returned assays of 1% Zn and anomalous levels of Pb and Ba. There is no indication if the pegmatite was mineralized. A diamond-drill hole (C-1-59; Meagher, 1966), put down to test a soil geochemical anomaly located a few hundred metres northwest of the McLaren workings, collared in a breccia zone from which there was only 15% core recovery. Most of the material recovered consisted of fragments of metawacke with common smears of galena. However, the bottom foot of the drillhole encountered pegmatite before the hole was lost due to a broken casing. The pegmatite is described as being "*intergrown quartz and white feldspar with minor white mica*" (Meagher, 1966). Sphalerite and pyrite are reported in the pegmatite. It is also interesting that the compilation map in Meagher (1966) indicates an outcrop of pegmatite about 10 m south of DDH C-1-59 and at the contact of metasediment with the granite pluton. Conceivably, the pegmatite encountered in the drillhole and this pegmatite outcrop may represent a single intrusion.

Meagher (1966) indicates an outcrop of pegmatite roughly 365 m west, and along strike of the beryl-bearing pegmatite at the McLaren workings. This outcrop is not discussed in his assessment file so it is not known if it is a firm indication of an extension of the beryl-bearing pegmatite or merely a minor dyke or vein.

Discussion

The presence of abundant beryl in the pegmatite at Lower Caledonia has significant exploration implications that warrant further attention. First, since the presence of high-grade beryl was not previously known, the extent of the Be enrichment in the pegmatite needs evaluation and the exact dimensions of the dyke need to be better defined. It is widely known that pegmatites tend to occur in swarms or groups of dykes. This observation holds true at Lower Caledonia where there is strong evidence that there is more than one pegmatite dyke present. In addition, pegmatites that host high concentrations of Be often host other economically important rare metals (e.g. Cs, Rb, Ta, Nb, Sn). Further exploration of the Lower Caledonia pegmatite(s) should address the potential for these other commodities.

Exploration at Lower Caledonia began with an interest in finding gold deposits then shifted to the potential for base metals. The relationship between berylium (inc. other rare metals?) mineralization, base metal mineralization and gold-bearing veins is, at present, poorly understood. Clearly, this relationship needs further evaluation. One common denominator is the spatial association of all three mineralization styles with the elongate leucogranite intrusions. This association goes farther afield than the Lower Caledonia area, as several other elongate, dyke-like intrusions of leucomonzogranite and leucogranite intrude the Meguma Group metasediments along tens of kilometres of the east-trending Cobequid-Chedabucto Fault Zone from Melrose to Trafalgar. Faribault (1886) provides a description of the granite plutons along this section and makes particular note of their elongate, dyke-like form. Plutons of several kilometres length are typically no more than a few hundred metres wide indicating a length to width ratio greater than 20:1. The plutons are deformed, but sporadically so and not to a degree consistent with the observed length to width ratios. Tectonic stretching of what was originally an undeformed pluton of roughly random or ameoboid shape, to the degree consistent with these ratios would result in complete recrystallization or mylonitization. This is not the case. The plutons display a planar fabric but much of the original magmatic texture remains. Typically, the central portion of the plutons exhibit only a weakly developed fabric. From this it is fair to conclude that their elongate form is, at least in part, a primary or syn-intrusion feature indicating the melts were emplaced into an actively shearing environment.

The numerous base metal occurrences and geochemical anomalies along this section of the fault zone and their association, at least spatially, with the elongate plutons is interesting to say the least. The realization that the granite magmas that gave rise to the plutons were exolving a fluid phase and producing a significant volume of pegmatite, and that these pegmatites are rich in rare metals, only furthers the economic potential of the area.

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Mineral Inventory Activities for 1999

G. A. O'Reilly and G. J. DeMont

Introduction

The field verification of mineral occurrences in the eastern shore region of the mainland and central Cape Breton Island continued to be a priority for the Mineral Inventory staff during 1999 (Fig. 1). In addition, staff directed attention to several project-related initiatives. G. J. DeMont worked with Industrial Minerals Geologist P. W. Finck and Mineral Promotions Geologist M. A. MacDonald examining the economic potential of several red marble and limestone prospects in the Kennedys Big Brook and Glen Brook (also known as Diogenes Brook) areas of Cape Breton Island. DeMont also assisted Geochemist T. A. Goodwin with a till and stream sediment geochemical survey in the Kennedys Big Brook area. G. A. O'Reilly provided field support as part of a cooperative effort between ASEDEX Minerals Corp. Ltd., College of Geographic Sciences, Dalhousie University Earth Sciences Department, Geological Survey of Canada and the Department of Natural Resources on the metasediment-hosted Eastville Zn-Pb Prospect near Upper Stewiacke. O'Reilly also carried out an examination of richly garnetiferous units within the Liscomb Complex southwest of Trafalgar, Guysborough County to evaluate their potential as a source of industrial garnet.

In addition, Version 4 of the DP-001b, the Mineral Occurrence Database, was released in October 1999. This release consists of information added to the database during 1999.

Field Activities

Figure 1 illustrates the NTS map areas in Nova Scotia in which field verification of mineral occurrences were carried out as well as the locations of other activities carried out by Mineral Inventory Program staff during 1999.

Eastern Shore Region

Field checking of mineral occurrences in the eastern shore region continued, for the third year, to be a priority of the Mineral Inventory Program. During 1999, most attention was concentrated on NTS map sheets 11D/13, 14, 15; 11E/01, 02, 07, 08; and 11F/04 and 06. These map sheets include a mix of gold and base metal deposits. Among the gold districts and prospects visited were Miller Lake, Lake Charlotte, Beaverdam, Wine Harbour, Little Liscomb Lake, Gegogan, Ragged Falls, Barneys Point and Lower Caledonia. Other sites visited were the Pembroke Pb-Zn prospect, Lazy Head W-Cu-Zn skarn, Enfield Quarry Zn occurrence, Waverly W prospect, Tickle V occurrence, Lake Charlotte Mn prospect and Boylston quartz crystal occurrence.

A pegmatite dyke, richly mineralized with beryl, was discovered during a field check of the Lower Caledonia gold prospect. Although the existence of the pegmatite dyke was noted when exploration and diamond drilling of the site for gold and base metals were carried out during the 1950s to 1970s, the presence of beryl was not recognized. The beryl pegmatite is being included as a separate occurrence in the database (E08-039) and a description of the mineralization and relationship to the Au-base metal mineralization are provided in a separate article in this volume (O'Reilly, 2000).

Liscomb Complex Garnet Gneiss

Geological mapping by the Nova Scotia Department of Natural Resources and Geological Survey of Canada in the late 1980s and early 1990s recognized the presence of the Liscomb Complex in the area between Trafalgar, Guysborough County and the eastern end of the Musquodoboit Valley (Giles *et al.*, in press). The northern half of the Liscomb Complex consists predominantly of a diverse suite of granitoid rocks ranging in composition from tonalite to leucomonzogranite. The southern half is dominated by high metamorphic grade felsic-intermediate gneissic rocks. Diatreme-like intrusions of gabbro and quartz-gabbro, rich in enclaves and xenoliths, are found to have intruded both the Liscomb Complex gneisses and Meguma Group metasedimentary rocks.

Earlier mapping recognized concentrations of boulders of garnet-rich gneiss restricted to the area surrounding Pogue Lake and northeast toward Trafalgar. Garnet in these boulders occurs as coarse, well-formed crystals and reaches concentrations of 25-30 modal %. During the past field season G. A. O'Reilly examined the economic potential of these unit(s) as a source of industrial grade garnet. An attempt was made to locate the source(s) of the boulders or, at least, narrow down

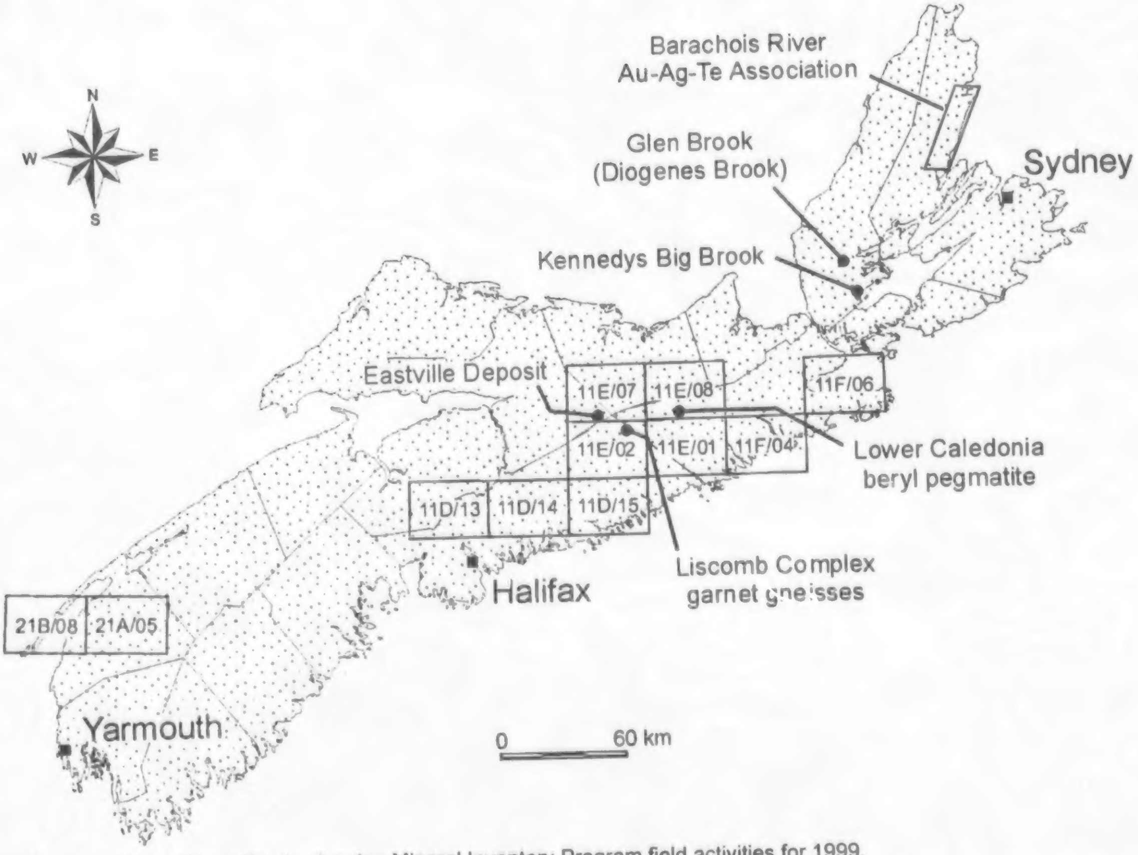

Figure 1. Map of Nova Scotia showing Mineral Inventory Program field activities for 1999.

the region in which they occur. Only four outcrops of garnet gneiss were located, but none contain the high concentration of garnet noted in the boulders. However, a close association of the garnet boulders with a series of medium- to high-amplitude second derivative vertical gradient anomalies (King, 1997) underlying the area between Pogue Lake and Trafalgar (Fig. 2) strongly suggests a relationship with a particular unit(s) within the Pogue Lake metamorphic suite that underlies that area.

A large boulder sample of garnet-bearing gneiss was collected and processed at the Minerals Engineering Centre, DalTech Campus, Dalhousie University, Halifax. The 13.63 kg sample produced a 2.09 kg (15.33%) garnet separate of various size fractions. Testing of the quality of this garnet separate is planned.

Weymouth Area

The Geological Mapping and Geochemistry Section of the Department is currently mapping lower to middle Paleozoic metasedimentary rocks in the Weymouth and Church Point areas of southwestern Nova Scotia (NTS map sheets 21A/05, 21B/08; Fig. 1; Horne *et al.*, 2000). The Mineral Inventory Program provides updated information about mineral occurrences. The mapping has discovered several new mineral occurrences and these were visited and sampled during the field season. Well developed skarn zones in upper Goldenville Formation units are exposed along the sea shore at Gilberts Cove and in the Weymouth Mills spillway (a portion of the Sissiboo River hydro-power system). In addition, the mapping recognized the presence of a subcropping 2-mica leucomonzogranite intrusion in the area of Clayton Hill a few kilometres southeast of Weymouth, and a significant distance west of the South Mountain Batholith. A recent logging road in that area has unearthed numerous boulders of mineralized and hydrothermally altered leucogranite. Mineralization in the boulders consists of quartz veins with greisen selvages containing molybdenite and chalcopyrite as well as pervasive alteration with disseminated pyrite and minor chalcopyrite.

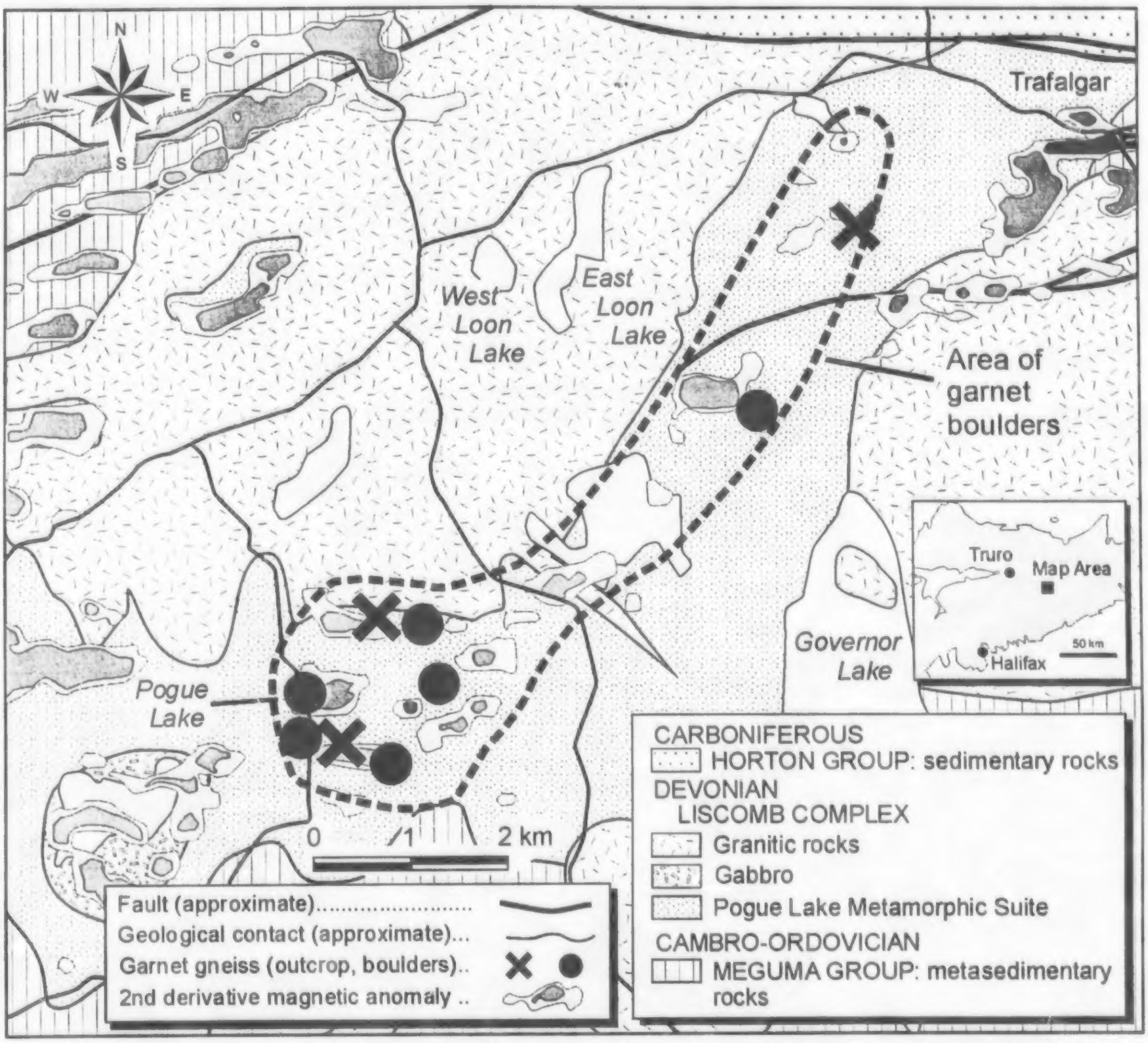
N
W
E
S
Trafalgar
West Loon Lake
East Loon Lake
Area of garnet boulders
Governor Lake
Pogue Lake
Truro
Map Area
Halifax
50 km
0
1
2 km
Fault (approximate)........................
Geological contact (approximate)...
Garnet gneiss (outcrop, boulders).. ✕ ●
2nd derivative magnetic anomaly ..
CARBONIFEROUS
HORTON GROUP: sedimentary rocks
DEVONIAN
LISCOMB COMPLEX
Granitic rocks
Gabbro
Pogue Lake Metamorphic Suite
CAMBRO-ORDOVICIAN
MEGUMA GROUP: metasedimentary rocks

Figure 2. Geology (after Giles et al., in press) and second derivative vertical gadient aeromagnetic map (after King, 1997) for the Trafalgar-Pogue Lake area showing the location of boulder clusters of garnet gneiss within the Liscomb Complex.

Central Cape Breton

Field examination of mineral occurrences of a Au-Ag-Te association in the Barachois River-Indian Brook area was carried out by G. J. DeMont. This is a continuation of work initiated previously in which DeMont discovered several new occurrences of this association during field checks of previously known precious metal occurrences in the area.

During the field checking of mineral occurrences in the Glen Brook (also known as Diogenes Brook) area a previously unknown red marble unit was discovered within Precambrian George River Group rocks. Follow-up mapping by DeMont suggests the unit has lateral extent and, therefore, economic potential. This aspect will be examined further as part of the cooperative effort outlined in the following section.

DeMont provided mapping support to Natural Resources Geochemist T. A. Goodwin as part of a geochemical pilot project in the Kennedys Big Brook area (Goodwin, 2000). The project examined the base and precious metal expression in glacial tills and stream sediments along a fault zone in an area of mixed metasediments and carbonates of Precambrian age.

Kennedys Big Brook Marble Project

G. J. DeMont collaborated with Industrial Minerals Geologist P. W. Finck and Mineral Promotions Geologist M. A. MacDonald to provide advice and geological mapping support to a consortium consisting of the Strait Highlands Regional Development Agency, Nova Scotia Department of Economic Development and Enterprise Cape Breton. The consortium is examining the economic potential of several red marble and limestone prospects in the Kennedys Big Brook area. As of January 2000, the consortium had just made final funding to undertake a diamond-drill examination of the sites. The necessary approval permits are being obtained after which the drilling is expected to begin in February 2000. A more detailed description of this project is provided in DeMont *et al.* (2000).

Version 4 of the Mineral Occurrence Database

Version 4 of the Mineral Occurrence Database (DP-001b) was released to the public in October 1999. This release consists of information added to the database since Version 3 of the database was released in February 1999. With Version 4, the Mineral Occurrence Database has information for 1190 metallic and 869 industrial mineral occurrences. The Mineral Occurrence Database, Version 4 (DP-001b) and the Computer Query Program designed to view, search and print the data in the database (DP-001a) are available free-of-charge from our branch internet site (URL www.gov.ns.ca/natr/meb) or at minimal cost from the department's library.

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Goodwin T. A. 2000: C horizon till and stream sediment geochemical survey, Kennedys Big Brook, Inverness County, Cape Breton Island, Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 1999, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 2000-1.

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Aggregate Program

G. Prime

Each year more than ten million tonnes of sand, gravel and crushed stone are extracted from pits and quarries throughout the province. This annually represents approximately fifty million dollars and more than five hundred jobs to the economy. As fundamental structural materials, aggregates play a key role in the construction industry and the development of our infrastructure. From highways to dams to water filtration systems to play sand, aggregate affects all aspects of our society. However, maintaining an adequate supply of these materials for our needs is becoming an increasing challenge. This largely reflects the population growth and industrial expansion that we have experienced in the last couple of decades. Issues such as increased market demands, land-use conflicts, and competition for the resource land have resulted in a decrease in aggregate reserves. This has become particularly troublesome near the more populated centres of the province which, ironically, are the areas where aggregate materials are needed the most.

In recognition of the growing concerns for the future of the resource, the Aggregate Program was established by the former Mines and Minerals Branch more than two decades ago. Today the primary goals of the program are: (1) to identify and evaluate the aggregate resource throughout the province, (2) to promote its protection for the future, and (3) to identify new economic opportunities for the resource. Since its inception, the Aggregate Program has examined both surficial and bedrock aggregate potential. This has included a province-wide mapping project, more detailed regional studies and a diamond-drilling program. There have also been several specialized projects examining new economic opportunities for aggregate. This has included identification of aggregate deposits with export potential and testing of aggregate fines as slow-release fertilizers and as consituents in the manufacture of synthetic topsoil. Field work for the Aggregate Program has also provided the opportunity to examine the potential for other industrial minerals, such as clay and building stone deposits.

The current focus of research is an evaluation of the aggregate resource in the Annapolis Valley region (Fig. 1). Initiated in 1995, the Annapolis Valley Project consists of field mapping the surficial and bedrock aggregate potential in Hants, Kings, Annapolis, Digby and Yarmouth Counties. The study has involved literature research, field work, air photo interpretation and preparation of maps and reports. The procedure for a study area begins with background research, identifying any previous work done in the project area. This can include examination of geological maps and reports, groundwater studies, geophysical surveys and diamond-drill data. This is followed by a preliminary look at the most recent air photos covering the area to identify the location of pits, quarries and landforms which should be examined during the field investigation. The field work phase involves traversing all accessible roads in each county. Modern forestry practices have resulted in construction of a large and growing network of woods access roads, opening huge, previously inaccessible areas to field examination. Although this has slowed the progress of field work considerably, it has permitted access to very remote parts of the province and a more thorough inventory of the aggregate resource in many regions. While travelling through an area, as many exposures as possible are examined. This includes road and ditch cuts, excavation sites, pits and quarries, shore line exposures, and natural outcrop. Landforms with aggregate potential are also investigated. At locations where no surface exposure is present, a shovel, auger or mattock is used to determine if sand and gravel are present. The characteristics of each site are then documented using a standardized data sheet. In addition to recording standard sedimentological and lithological data, other characteristics, such as aggregate extraction history and potential land-use conflicts, are documented where available. Finally, the field data are used in conjunction with a detailed examination of air photos to categorize the depositional origin of the surficial deposits and to delineate their areal extent.

Approximately 3500 site descriptions have been compiled for the project to date. Materials documented include sand, gravel, till, residuum, talus and bedrock. Many of the promising sand/gravel and bedrock deposits have been sampled to determine aggregate quality. Laboratory tests conducted on the samples include sieve analysis, Petrographic Number, $MgSO_4$, Soundness Loss, LA Abrasion Loss, and micro-Deval Abrasion Loss. Collectively the information will be processed as point data and descriptive fields in an ArcView® database. Using air photo interpretation, the areal extent of the deposits will be delineated and entered as a polygon digital data set. The result will be a series of 1:50 000 Scale resource maps showing the surficial and bedrock aggregate potential.

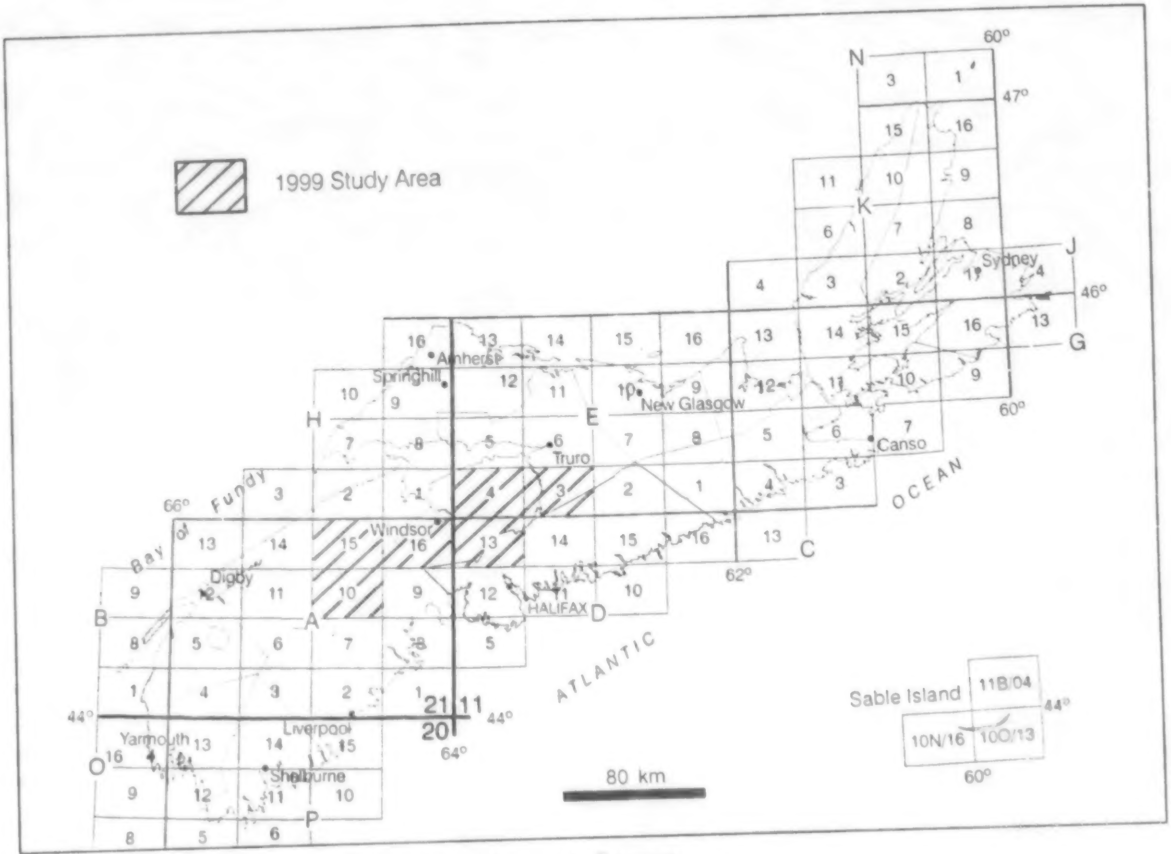

Figure 1. Field studies carried out in 1999 for the Aggregate Program.

The focus of the 1999 field season was completion of Hants and Kings Counties and included field work in parts of NTS map areas 11E/03, 11E/04, 11D/13, 21A/10, 21A/15 and 21A/16. Air photo interpretation of Hants and Kings Counties will be conducted in 2000. Digital aggregate resource maps for each county will be released as they are completed.

The Tangier Gold Deposit (NTS 11D/15A): Underground Gold Assay Results from the Whin Vein

P. K. Smith

Introduction

It is reported that the discovery of gold at Tangier was the first in Nova Scotia, dating back to 1860 (Malcolm, 1929). The main historical development at the district took place from the Kent Shaft which is located immediately east of the Blueberry Hill mine in the village of Tangier along the north side of Highway 7 (Fig. 1a). Recent development of this mine site was carried out by Coxheath Gold Holdings Ltd. from 1986 to 1989, when a development and production decline to the 120 m level was driven by the company, in addition to over 5 km of underground drifting and raising. Their work was carried out primarily on the Marker, Whin, Twin and Nugget veins, with minimal development on the Big and Little South veins (Fig. 1b). Poor mill recoveries eventually drove the company into receivership in 1989.

In 1997, privately funded Tangier Limited Partnership (TLP) acquired the Blueberry Hill gold mine at Tangier (Fig. 1) from the provincial receiver by submitting a work proposal to put the mine into production. After initial underground test mining using a high production jumbo drill on the Marker, Whin and Twin leads, the company installed an underground crusher and constructed an underground-to-surface conveyor belt. In 1998, modification to the company's on-site milling facility was finalized and a mining lease was granted to TLP to proceed with the operation. Total staff employed at the mine increased to approximately 75 persons.

However, in early 1999, TLP experienced financial trouble as a result of problems with low ore grade and recovery, despite the visible gold commonly found throughout the working faces. In April, the company approached the Nova Scotia Department of Natural Resources (DNR) to help verify the ore grade of an approximately 20 tonne sample recently collected and crushed from the Whin Vein adjacent to the fold hinge at the 12-55 south-drift-west (SDW) heading (Fig. 1). The company crushed the entire round to <2 mm with a Baramack crusher and processed ~10 tonnes of ore at their on-site facility using Kuryluk Mineral Separator (KMS) gravity concentrators. The remaining ~10 tonnes of the bulk sample was shipped to the Minerals Engineering Centre analytical facility at the Technical University of Nova Scotia on the DalTech campus, Halifax.

To assist Tangier Limited Partnership in evaluating the gold content of this ore round, and also to help keep the mine active, DNR decided to collect representative samples from the active face area of the Whin Vein where the ~20 tonne sample had been previously taken. In consultation with the department's Engineering Section and two consulting mining engineers, samples were collected from: (1) the face (behind the round), (2) the floor in front of the face (to assess potential loss during mucking), (3) beneath the underground conveyer (to verify if there was any gold loss during transport of ore and waste from underground to surface), and (4) under the fine ore belt (above ground) which carried only gold ore to the primary crusher. In addition, two samples were collected at a later date from the tailings to determine if any gold was being lost from the milling circuit.

All assay and analytical work was carried out at DalTech using a combination of gravity separation (jigs, Knelson concentrator and table) and cyanide extraction. Visible gold from the face samples was examined and photographed by the author, and returned to the individual samples prior to crushing and analysis. The results of the face, floor, belt and tailings samples are reported herein. Bulk sample results from the ~20 tonne ore sample will be reported at a later date.

General Geology

Gold at Tangier occurs primarily in a series of bedding-parallel veins along the south limb of the upright Tangier Anticline (Fig. 1b). Although mineralized veins extend around the hinge to the north limb of the anticline, virtually all historical production (26,000 oz.) came from the south limb. Approximately 70 gold-bearing veins were identified in the Blueberry Hill mine during its mine history and associated diamond-drilling. In addition to smaller veins that occur within the mine sequence adjacent to these 70 veins, numerous others occur along strike toward the east in the Strawberry Hill and East Ore Zone areas (Fig. 1a).

The deposit is characterized by tight, upright regional folds with penetrative slaty cleavage in pelitic

Table 1. Description of underground and surface samples analyzed for this study.

Sample #	Rock Type	Weight (kg)	Assay Method
TAN99-UG-B	Mixed ore and waste dropped off of the underground conveyor	41.8	(1) wet screening (2) crushing to -2 mm (3) cyanidation by bottle roll
TAN99-OR-B	Very fine-grained ore dropped off of the fine gold ore belt	8.2	Bottle roll cyanidation as received
TAN99-W3	Loose muck from the floor in front of active face left behind after ore removal	35.63	(1) wet screened (2) crushed with jaw and cone crusher with final crushing to -2 mm with a hammer mill (3) jig concentration (4) cyanidation of jig concentrate (5) further grinding and cyanide leaching by bottle roll (6) aqua regia leach of jig tails
TAN99-W4	Chip sample of quartz and silty-pelite ore horizon from the *south* side of the active face, representative of the back of the assayed bulk round	34.96	(1) similar process to TAN99-W3
TAN99-W5	Chip sample of quartz and silty pelite from the *north* side of the active face representative of the back of the assayed round	39.2	(1) similar process to TAN99-W3

TAN99-UG-B and TAN99-W3. The +80 mesh fractions for samples TAN99-W4 and -W5 were analyzed without pulverizing and the samples were filtered, dried, pulverized and re-leached.

Gold Grain Analysis

Gold grains were collected and photographed from samples TAN99-W3, -W4 and -W5 (Fig. 3), and then returned to each individual sample prior to crushing or analysis. Grain size varied from ~10 μm to ~2 mm. Textures varied from irregular to crystalline nuggets, fine wires, and apparently deformed grains with no obvious crystal shape. Clusters of gold grains were as common as individual grains. These clusters generally occurred as one or two larger grains (~0.25 to 0.5 mm) surrounded by numerous smaller ones. Upon crushing, these larger clusters were reduced to individual, smaller grains. Several gold grains were observed included within and attached to arsenopyrite grains. No examples of gold in host rock were observed in these samples.

Although microprobe analysis was not carried out on any of these grains, samples collected during earlier investigations of the district contained approximately 4 wt. % Ag.

Results

Close examination of the bottle test tails for sample TAN99-W4 showed that this sample still contained gold which had not been completely leached. This sample was further pulverized to <0.25 mm, but no gold was found on the screen. The grinding equipment was cleaned with sand and the sand was analyzed by bottle roll cyanidation. This test showed that 75% of the remaining gold had been lost to the pulverizing equipment. Gold was smeared on the walls of the equipment as well as on individual quartz particles, and subsequently discarded into the tails.

In addition, the lab report noted the following: The larger gold particles were thick and should be recovered with a jig by crushing the ore to -2 mm or to -1 mm with an impact mill. An impact crusher would thicken the gold and this should improve recovery with gravity equipment." The report also noted: "High recoveries could be obtained by cyanidization but larger gold particles would have to be ground to flat particles to lower the leaching times. The test work showed that the coarse gold was not completely leached after 48 hours." With respect to recoveries it was stated that: Recoveries of 80.0% were achieved with the jig. No effort was

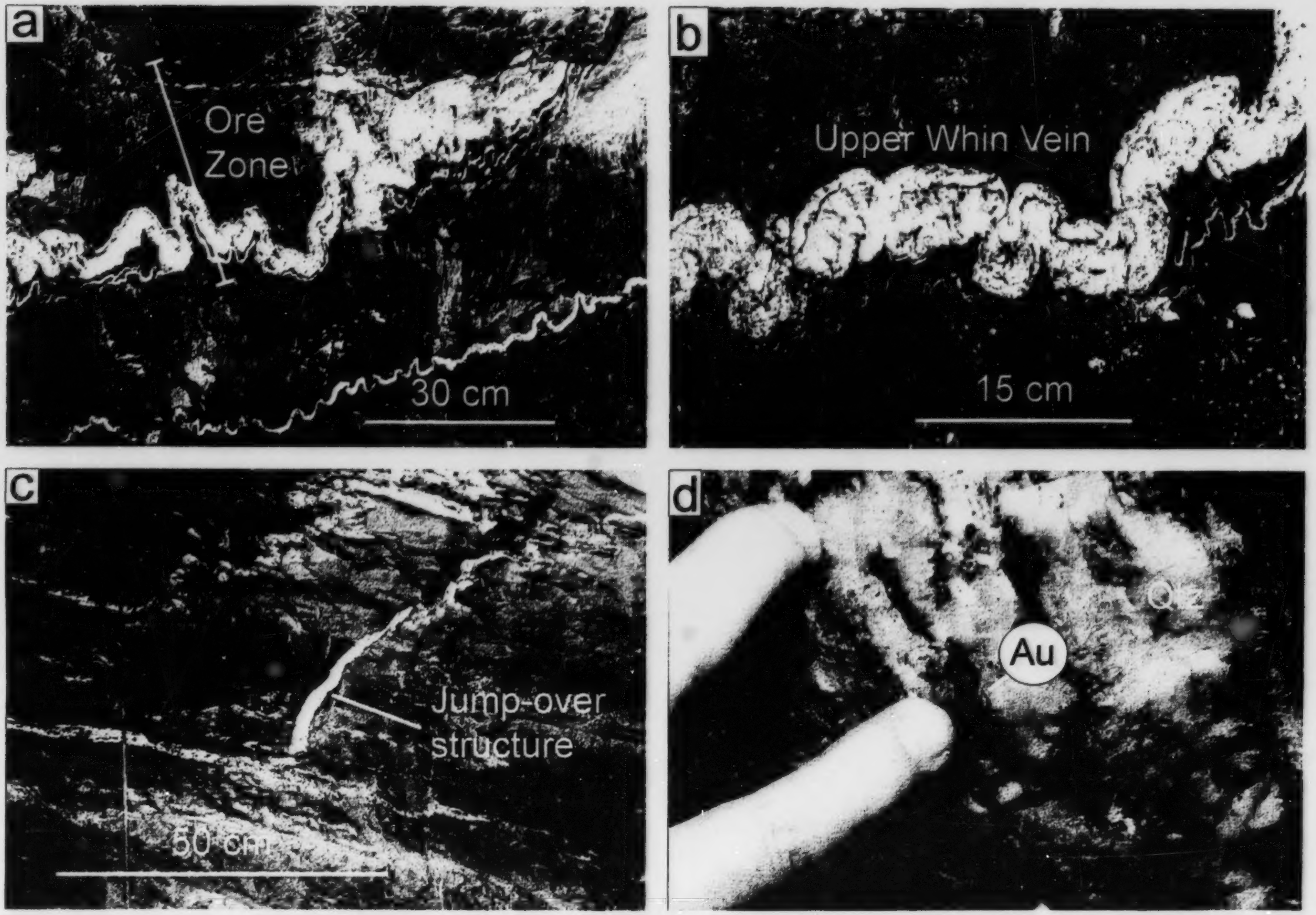

Figure 2. Photographs of the Whin Vein at the face of the 12-55 south-drift-west heading. (a) Shows the ore zone (white line) that was sampled for this study (samples TAN99-W4 and -W5). (b) Close-up of the Whin Vein along the central part of the face. (c) A 'jump-over' structure immediately east of the sampled face; gold is transported from the lower vein to the upper vein along this discordant vein. (d) Match-head sized gold grain surrounded by several smaller grains in massive white quartz adjacent to a slate inclusion.

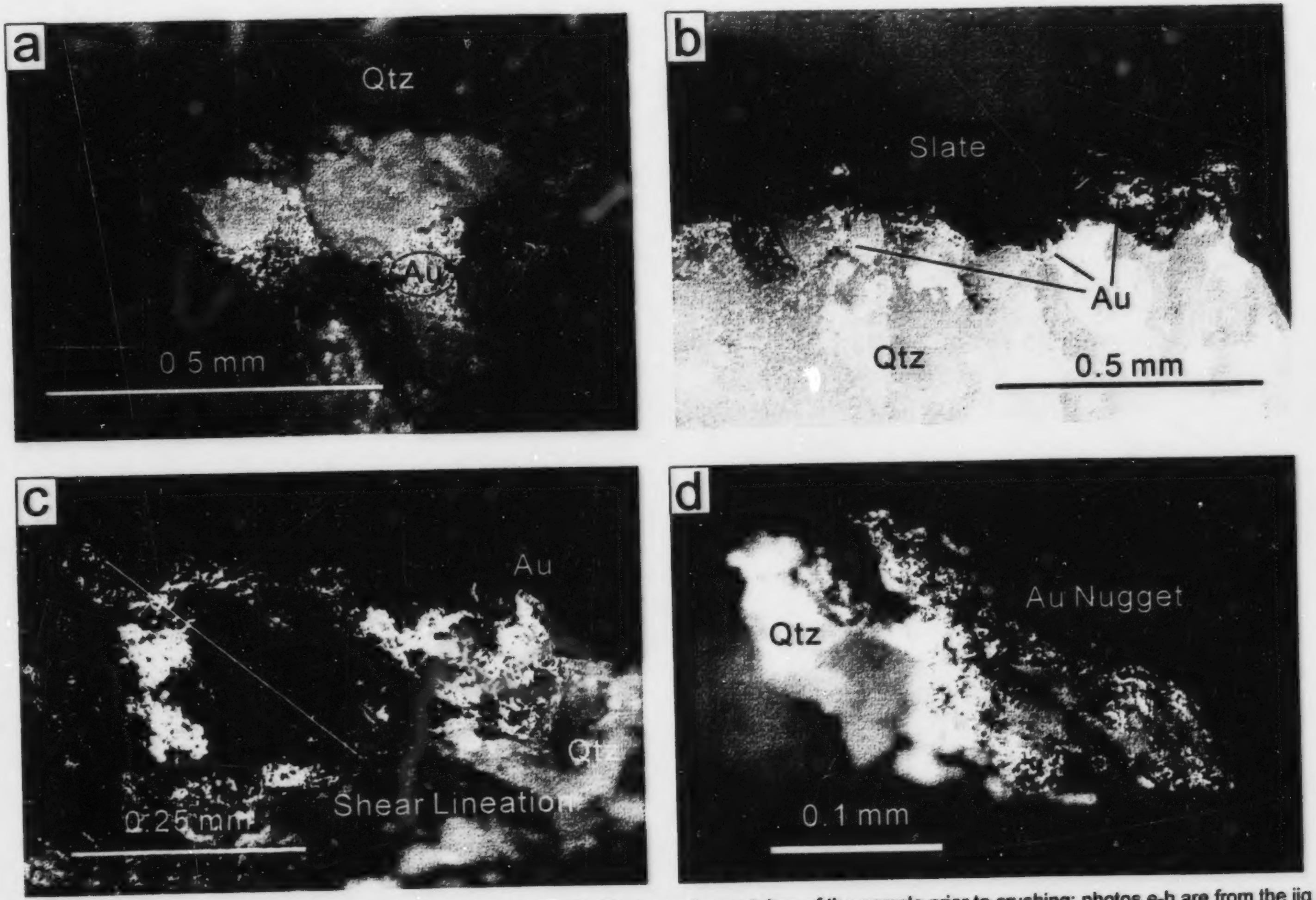

Figure 3. Gold grains collected from samples TAN99-W4 and -W5. Photos a-d were taken of the sample prior to crushing; photos e-h are from the jig concentrates. (a) Gold grain occurring along quartz grain boundaries. (b) Abundant gold grains in both quartz and slate at the massive white quartz vein margin. (c) Shear lineation in pyrrhotite-arsenopyrite and gold at the margin of massive white quartz. (d) Irregular wire-like nugget protruding from white quartz. (e) Small portion of the grains collected from the jig concentrates. (f) Delicate gold with attached quartz. (g) Three different coloured gold grains from the jig concentrate. (h) Rounded gold grains caused by crushing and agitation in the jig.

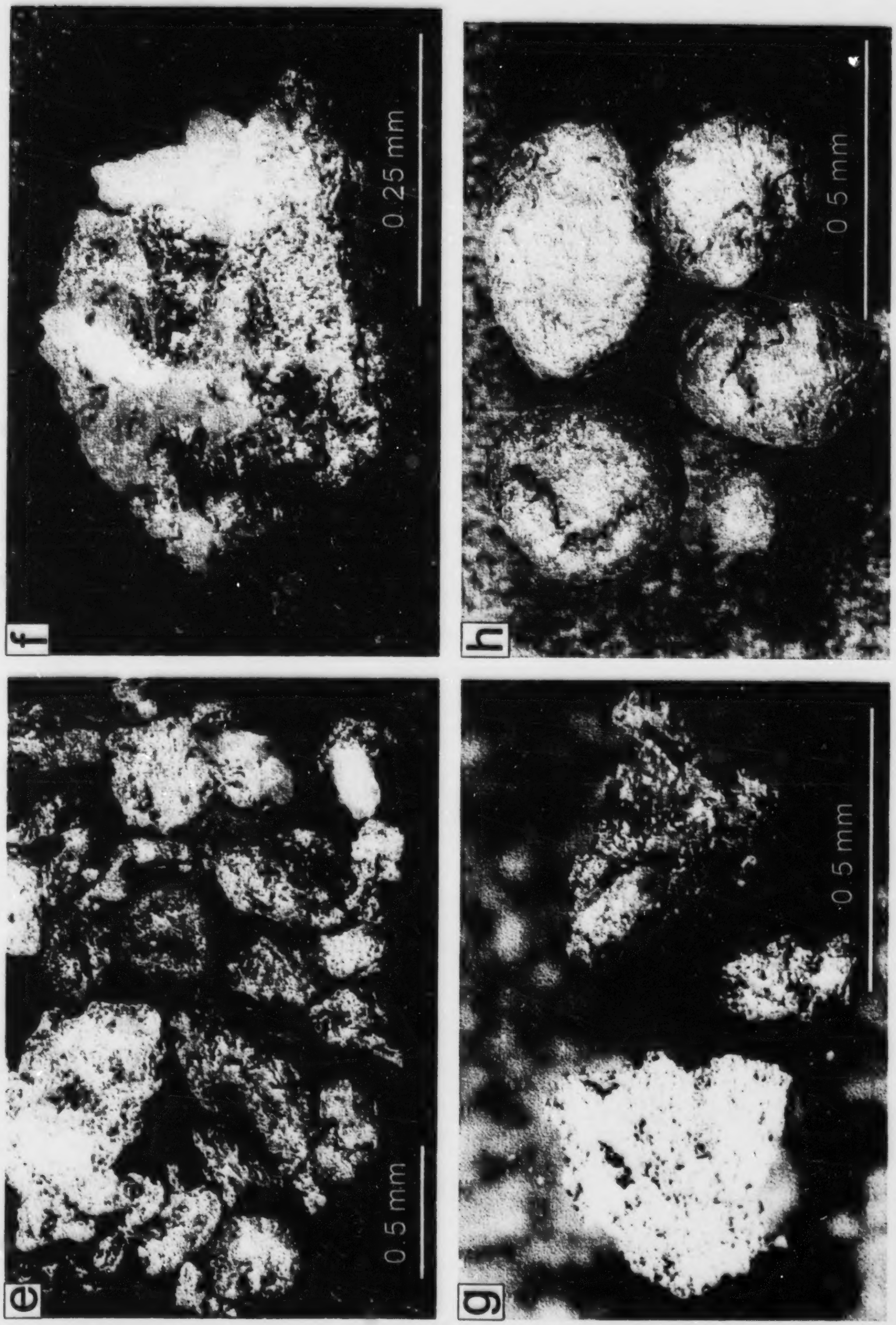

Figure 3. continued.

Table 2. Analyses of head sample by bottle Roll Cyanidation.

Sample #	Au Extracted by Cyanide (ppm)	Tails (ppm)	Total (ppm)	% Au Extracted by Cyanide
TAN99-OR-B	2.34	0.035	2.375	98.53
TAN99-UG-B	6.10	0.146	6.246	97.66
TAN99-UG-B	6.49	0.144	6.534	99.33

Table 3. Calculated head analyses from gravity tests.

Sample #	Gold Grade (ppm)
TAN99-UG-B	9.71
TAN99-OR-B	2.375
TAN99-W3	2.62
TAN99-W4 & W5	70.85

made to optimize the equipment. With optimization, recovery would be higher. The -0.15 mm gold could be recovered with centrifuge equipment." Tables 2 through 9 summarize the analytical work on the five samples.

Results From Tailings Pond

Two samples, weighing ~4 kg and ~5 kg, were collected from tailings at the back of the mill to determine if any gold was being lost during the milling circuit (Table 10). The first sample (TAN99-Tails-1) included all material from the top 25 cm of tailings material, whereas the second (TAN99-Tails-S) preferentially sampled a 2 mm thick sulphide-rich layer exposed at surface. This sample was estimated to contain about 25% mixed sulphides (mainly arsenopyrite and pyrrhotite). Because of the small sample number, no definitive conclusions should be drawn regarding the total amount of gold contained in the tailings area.

Samples were split into two fractions with one being sent for cyanidization and the second retained for further investigations. The results are shown in Table 10.

Discussion

The presence of a 'jump-over' structure on the Whin Vein appears to control the distribution of gold ore at this site. This feature allowed gold to move from the lower Whin Vein (ore bearing to the east) upward in a westerly direction into the upper Whin Vein. In addition, there is a set of steeply plunging kink bands adjacent to this jump-over structure with a fold axial plunge similar to the intersection lineation between the angular jump-over vein and bedding. The close association of these minor structures and high-grade gold mineralization suggests that these structures may be used to predict the location of high-grade ore throughout the deposit.

Visible gold is common in the ore samples taken from the Whin Vein for this study of the Blueberry Hill Mine (Fig. 2d, Fig. 3). Analyses for the face sample returned a concentration of 70.85 ppm Au with a recovery of 80.36% using conventional gravity separation with 19.94% of the gold in the tails fraction (Table 6). Bottle roll cyanidation of the jig material (concentrate and cell) and tails shows recovery of virtually all of the gold (91.81 - 99.90 %) although, coarser grained gold had to be crushed to a smaller size by regrinding (Table 7). However, the potential for gold to smear on the surfaces of the crushing equipment and quartz grains is high, as indicated from sample TAN99-W4 (Table 9). Under these conditions, a large amount of gold will not be recovered by simple gravity methods and may be lost to the tailings. Examination of the tails material shows that between 48.76 % (TAN99-W3) and 75.90% (TAN99-W4 and -W5) of the remaining gold is coarser than 80 mesh (Table 8).

Samples taken from the floor in front of the face, beneath the underground ore and waste belt, and in the tailings suggest considerable (2.62 ppm) gold loss (Tables 3 and 5). Although gold was detected in fine-grained material from under the fine ore belt (2.375 ppm), the actual total volume of material under the belt is small (~1 tonne) and hence, the total gold loss is regarded as insignificant. However, the high gold assays (9.71 ppm) from abundant material lying under the underground conveyor (Table 3 and 4), which carried both ore and waste (TAN99-UG-B), should be considered excessive given the relatively short duration of the operation.

Based on laboratory analysis of these samples the gold grade of ore in the Whin Vein at the 12-55 south-drift-west is 70.85 ppm. Hence, if gold recoveries in the mill do not reflect these grades then it can be assumed

Table 4. Jig test results for sample # TAN99-UG-B (*Calculated Head Grade = 9.71 ppm Au).

Sample Fraction	Weight (g)	% Weight	Au (ppm)	% Distribution
Concentrate	682.4	1.63	381.73	64.06
Cell	468.8	1.12	150.22	17.32
Tails	40 648.8	97.25	1.86	18.62
Total	41 800.0	100.00	9.71*	100.00

Table 5. Jig Test Results for Sample # TAN99-W3 (*Calculated Head Grade = 2.62 ppm Au).

Sample Fraction	Weight (g)	% Weight	Au (ppm)	% Distribution
Concentrate	324.1	0.91	185.23	64.29
Cell	669.2	1.88	1.66	1.19
Tails	34 636.7	97.21	0.93	34.52
Total	35 630.0	100.00	2.62*	100.00

Table 6. Jig test Results for sample # TAN99-W4 & W5 (*Calculated Head Grade = 70.85 ppm Au).

Sample Fraction	Weight (g)	% Weight	Au (ppm)	% Distribution
W4 Concentrate	573.3	0.77	5200.5	56.52
W4 Cell	682.7	0.92	427.36	5.55
W5 Concentrate	502.6	0.68	1784.6	17.13
W5 Cell	691.8	0.93	88.55	1.16
Tails	71 709.6	96.7	14.39	19.64
Total	74 160	100	70.85*	100

Table 7. Bottle roll cyanidation results of jig concentrates and cell material.

Sample #	Au (ppm) after 24 hours	Au (ppm) after 48 hours	After Regrind (ppm Au)	Total (ppm Au)	Bottle Test Tails (ppm Au)	Combined Total (ppm Au)	% Au extracted by Cyanide
UG-B Jig concentrate	249.12	ND	101.36	350.48	31.25	381.73	91.81
UG-B Jig cell	27.73	ND	121.52	149.25	0.97	150.22	99.35
W3 Jig concentrate	88.86	158.23	26.81	185.04	0.19	185.23	99.9
W3 Jig cell	0.7	0.9	0.75	1.65	0.01	1.66	99.4
W4 Jig concentrate	2481	3250	1715	4965	235.5	5200.5	95.47
W4 Jig cell	78.8	188.52	238.27	426.79	0.57	427.36	99.87
W5 Jig concentrate	1509	1684	98	1782	2.62	1784.6	99.85
W5 Jig cell	13.08	33.06	55.17	88.23	0.32	88.55	99.64

Table 8. Bottle roll cyanidation results of jig tails on TAN99 samples.

Sample #	% Weight	Au (ppm) after 24 hours	Au (ppm) after Regrind	LeachedAu (ppm)	Bottle Test Tails	Au (ppm) Total	% Au Distribution
UG-B (+80 Jig Tails)	71.59	1.68		1.68	0.03	1.71	65.9
UG-B (-80 Jig Tails)	28.41	2.2		2.2	0.03	2.23	34.1
Calc. Head	100	1.86					100
W3 (+80 Jig Tails)	71.07	0.64		0.64	0.003	0.643	48.76
W3 (-80 Jig Tails)	28.93	1.56		1.56	0.08	1.64	51.24
Calc. Head	100	0.93					100
W4& W5 (+80 Tails) Run #1	40.92	8.01	4.34	12.35	0.13	12.48	35.5
W4& W5 (-80 Tails) Run #1	9.02	17.72		17.72	1.47	19.19	12.03
W4& W5 (+80 Tails) Run #2	41.07	8.54	5.44	13.98	0.17	14.15	40.4
W4& W5 (-80 Tails) Run #2	8.99	18.44		18.44	0.87	19.31	12.07
Calc. Head	100	14.39					100

Table 9. The smearing effect of gold particles caused by grinding in sample TAN99-W4.

Sample #	Au (ppm)	% Au Distribution
TAN99-W4 (Jig Concentrate)	437	25.5
Cleaning sand used in pulverizing equipment	1278	74.5
TOTAL	1715	100

Table 10. Bottle roll cyanidation results on two samples from the tailings pile.

Sample #	Description	Weight (g)	Au (ppm)
TAN99-Tails-1	25 cm core section below outflow pipe	2865.01	4.54
TAN99-Tails -S	Sulphide-rich horizon on surface of tailings 10 m from outflow	1733.94	12.79

that gold is being lost by one, or all, of the following mechanisms: (1) dilution at the face resulting in higher tonnage and lower gold grade per ton, (2) loss of gold on the floor and along the transportation route to the mill, and (3) gold remaining in the tailings. Preliminary results from the bulk sample currently being analyzed at TUNS suggest that all of the above were contributing factors for less than optimum gold recovery at the Blueberry Hill Mine.

References

Faribault, E. R. 1902: Geological mine surface plan and section of the Tangier gold district, Halifax County, Nova Scotia; Geological Survey of Canada, Map 773, scale 1:3000.

Malcolm, W. 1929: Gold fields of Nova Scotia; Geological Survey of Canada, Memoir 156, 253 p.

Palaeoecology and Sedimentology of Fossil Lycopsid Forest Successions in the Classic Upper Carboniferous Section at Joggins, Nova Scotia[1]

J. H. Calder[2], M. R. Gibling[3], A. C. Scott[4], S. J. Davies[5] and B. Hebert[6]

Standing lycopsid trees occur minimally at 50 horizons within the 1425 m thick coal-bearing interval of the classic Carboniferous section at Joggins, with one of the most productive intervals, discussed here, ocurring between coals 29 (Fundy seam) and 32 of Logan (1845). The majority of trees, invariably rooted within an organic-rich substrate, are entombed by heterolithic units in the order of 5m thick that can be traced to distributary channel bodies of similar thickness. The heterolithic strata are inferred to represent the recurring overtopping of distributary channels, from which they record highly oblique paleoflow. Flooding surfaces are represented by thin bivalve-bearing beds. The sequence stratigraphic motif of the fossil forests is one of stacked parasequence sets; the virtual absence of sequence boundaries reflects the excessive rate of basin subsidence. Candidates for erect lycopsids (dbh 25 to 50 cm, spaced ≥1.14 m) from prostrate compressions include *Sigillaria*, *Lepidodendron*, *Lepidophloios* and ?*Paralycopdites* (*Ulodendron*), representing a broad range of ecological preferences. Permineralized, charred trunks of ?medullosan affinity occur rarely. Associated compression flora includes lycopsid, calamite, pteridosperm, fern and progymnosperm litter. Sudden burial of lycopsid trees by onset of heterolithic deposition resulted in the demise of entire stands. Disturbance adapted calamites persisted in the episodically accruing sediment, apparently able to regenerate adventitiously from branches with exposed apical meristems. The faunal record of this fossil forest interval includes a Megasecoptera, whip spider, *Dendrerpeton* described by Carroll *et al.* (1998) and several tetrapod ichnotaxa, including an undescribed species that may represent the top predator at Joggins.

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[1] XIV International Congress of the Carboniferous-Permian, Calgary, Program with Abstracts, p. 19.

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Superimposition of Quartz-carbonate-talc Sinter Deposits with Massive Sulphide Mineralization in a 680 Ma Hydrothermal Sea Floor Setting at Stirling, Southeast Cape Breton Island, Nova Scotia[1]

Daniel J. Kontak

The Stirling volcanogenic massive sulphide (VMS) deposit (historical production 1.2 Mt of 6.4% Zn, 1.5% Pb, 0.74% Cu, 2.2 oz./t Ag, 0.03 oz./t Au) is hosted by intermediate pyroclastics and finely laminated volcaniclastics of the Late Hadrynian (680 Ma) Stirling Group, SE Cape Breton Island. The volcanic strata are intruded by a quartz-feldspar porphyry (Stirling rhyolite) of elongate shape, which is subparallel to and underlies the ore zone along its 1500 m of strike length. Logging of drill core, surface mapping and a review of previous work indicate: (1) The footwall (FW) and hanging wall (HW) rocks consist of graded (cm to 3-4 m scale) volcaniclastics of intermediate composition; sedimentary features indicate tops are NW. (2) The Stirling rhyolite is a high-level, polyphase intrusion with variable crystal (quartz, feldspar) content (<3% to 25%), well-preserved spherulitic textures and Na-metasomatism. Eruptive equivalents may occur in the highest part of the stratigraphy. (3) Massive sulphides, consisting of finely laminated (tectonic ?) Zn-Fe-Cu-Pb sulphides dominated by Fe-poor sphalerite and pyrite, occur along a single horizon within a shear zone (Mine Shear). (4) Polyphase deformation has overturned the strata (dips 70-80° SE) and dismembered the sulphide mineralization. (5) The immediate HW and FW strata, now carbonate-talc schist, represent altered intermediate volcaniclastics and not felsic volcanic rocks, as previously considered by some workers. (7) Extensive zones (to 10s of m) of fine- to coarse-grained quartz-talc-carbonate (QTC) rock replace sections of both intermediate volcaniclastics and rhyolite porphyry throughout the FW. These zones formed from alteration processes and are not of exhalative origin. Minor disseminated calcite occurs as alteration in HW rocks. (8) The QTC is generally barren, but rare zones of disseminated to massive pyrite (±sphalerite, galena) occur. Textural observations suggest the QTC post-dates the sulphide rock. (9) In one locality a quartz-carbonate mound (palaeosinter deposit) underlies a 2 m thick massive sulphide zone. The above observations are interpreted to indicate that VMS mineralization and QTC zones formed from fluid focusing of heated sea water, but under different thermal and chemical conditions such that two distinct hydrothermal systems formed, one high temperature (ca. 250-300°C) and analogous to modern black smokers and the second a lower temperature (ca. 80-100°C) system akin to hot springs depositing travertine at Yellowstone Park, U.S.A. The porphyry unit is considered the source of thermal energy to initiate and drive the hydrothermal cells.

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[1] *in* Atlantic Geoscience Society, Annual Colloquium, Amherst, Nova Scotia; Atlantic Geology, v. 35, no. 1., p. 95-96.

[2] Department of Natural Resources, P. O. Box 698, Halifax, Nova Scotia B3J 2T9, Canada <djkontak@gov.ns.ca>

New Constraints on the Age and Origin of the Dunbrack Pb-Cu-Zn-Ag Deposit, Musquodoboit Batholith, Southern Nova Scotia[1]

Daniel J. Kontak[2], Kevin Ansdell[3], and Douglas Archibald[4]

Mineralization at the Dunbrack Pb-Zn-Cu-Ag deposit occurs within a ca. 1 m wide quartz vein characterized by comb, cockade, crustiform, and breccia textures. The mineralized vein, NW-trending and steeply dipping, has a medium- to coarse-grained, biotite-muscovite±cordierite monzogranite phase of the 370 Ma Musquodoboit batholith as its hanging wall and a fine-grained felsic dyke rock as its footwall. Silicate mineralogy in the vein is dominated by quartz with trace amounts of K-feldspar (Or_{86-100}), muscovite ($\leq$2 wt. % FeO, $\leq$0.8 wt. % F), chlorite, and kaolinite, whereas sulphides include Fe-poor sphalerite ($\leq$4 wt. % Fe), galena, chalcopyrite, and a variety of secondary Cu sulphides. Dating ($^{40}Ar/^{39}Ar$) of vein muscovite and the footwall dyke rock indicate similar ages of 370 Ma; therefore, vein formation and dyke injection are interpreted to be coincident with emplacement of the 370 Ma Musquodoboit Batholith.

Fluid inclusion studies of aqueous, L-V inclusions indicate homogenization temperatures of ca. 140 ± 5°C and salinities of 20 ± 2 wt. % eq. NaCl, but minor amounts of inclusions with higher (24 to 27 wt. %) and lower (8-16 wt. %) salinities occur. First melting temperatures and analysis of decrepitate mounds indicate two fluid types, a more abundant $NaCl\text{-}H_20$ fluid and a less abundant $NaCl\text{-}CaCl_2\text{-}KCl\text{-}H_20$ fluid.

Sulphur isotopes for hypogene galena, chalcopyrite, and sphalerite are uniform and equate to $\delta^{34}SH_2S$ of +4.2 to +6.6‰ (at 300°C), which is similar to data for other granite-related sulphide mineralization in the Meguma Zone. Vein quartz has an $\delta^{18}0$ value of +15.3 ± 1.2‰ (n=10), which equates to $\delta^{18}O_{water}$ of +9 to +11.5‰ at 300°C, whereas fluid inclusion extracts indicate δD values of -90 to -113‰ (n=6).

Collectively, the timing of mineralization (i.e., 370 Ma) and the dominantly magmatic isotopic and geochemical signature for the vein-forming fluid suggest a genetic association with the Musquodoboit Batholith. However, the Ca-rich nature of some fluid inclusions and low δD values of fluid extracts suggest involvement of another reservoir, possibly reflecting a fluid that equilibrated with the country rock of the Meguma Group.

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[1] *in* Atlantic Geology, v. 35, p. 19-42 (1999)

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Occurrence of Microgarnets Coring Plagiociase Crystals in Granodiorite of the South Mountain Batholith, Nova Scotia[1]

L. Ransom[2]*, B. Murphy*[2] *and D. J. Kontak*[3]

We report on the occurrence of microgarnets (<3 mm) occurring in the granodiorite phase of the South Mountain Batholith (SMB), a 370 Ma, polyphase peraluminous batholith that outcrops throughout southern Nova Scotia. Samples come from a diamond drill hole (NSDNR hole # DDH-1) collared in metasedimentary rocks of the Meguma Group near Digby, southwestern Nova Scotia. At depth the hole intersects variably altered, biotite-rich granodiorite which forms a marginal phase of the SMB. Within fresh granodiorite (samples taken from between 12-32 m, 102-104 m and 249-264 m depths) occur deep red microcrystals of garnet, of which some coexist with biotite, consistently occurring in the cores of plagioclase grains. We also noted the presence of small fragments (1-25 cm) of biotite-rich (ca. 30-40%) xenoliths scattered throughout part of the core. Bulk analyses of the granodiorite (n=12) indicate 68.92 wt.% SiO_2, 0.59 wt.% TiO_2 and a peraluminosity (A/CNK) of 1. 11. In thin section the rock is hypidiomorphic granular with normal and oscillatory zoned plagioclase (An_{18-45}), perthitic K-feldspar, dark brown biotite [Fe/(Fe+Mg) = 0.643] with abundant accessory phases, intragranular apatite and rare garnets invariably enveloped by plagioclase. Observations of about 25 garnets indicate anhedral shapes dominate and that reaction rims are totally absent. The majority of garnets analyzed occur within close limits of partially digested biotite-rich xenoliths, but in thin section no garnets have been observed in the xenoliths. Electron microprobe analyses indicate spessartine-rich almandine garnet compositions with a core to rim enrichment of Mn (i.e., 3 vs. 7 wt.% MnO). Currently a variety of models are being considered to account for the garnets, including xenocrystic (source yet unknown) and cognate (high- or low-P magmatic).

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[1] *in* Atlantic Geology, v. 35, p. 102 (1999)

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Evidence for a ~13 ka Glacier Advance in Atlantic Canada[1]

R. R. Stea

Was there a significant late-glacial advance correlative with the Port Huron event of the mid continent in Atlantic Canada? Data from Nova Scotia and the offshore supports the idea of an ice advance that occurred approximately 13 ka.

The Appalachian Ice Complex was a series of Wisconsinan ice centres, spatially and temporally distinct, that advanced and retreated producing a palimpsest of erosional and depositional glacial landforms. Four main phases of ice flow have been recognized, with the youngest event termed the Chignecto Phase. This flow was largely directed into marine bays bordering Nova Scotia, although striae relating to this phase are found on 300 m highland areas near the former ice centres. These southwestward flow patterns can be traced to ice marginal deposits in southwest Nova Scotia, northern Nova Scotia and the inner Scotian Shelf. Ages of the ice margins were established by direct dating of a glaciomarine delta and by bracketing ages through AMS dating of lake sediment cores beyond and behind the margins. The timing of deglaciation was established using a linear regression model of AMS ages vs depth of organic gyttja beneath a distinctive Younger Dryas marker horizon.

The average basal accumulation age of four lakes behind the onshore Chignecto Phase margins is 11.6 ka, whereas five lakes beyond the margin averaged 12.9 ka . Three shell fragments from a glaciomarine delta beyond the margin averaged 13.5 ka. The minimum age can be significantly increased by considering a deglaciation age of 12 ka from buried peat at the head of the Bay of Fundy, and adding 200 varve years of glacial lake sediment that pre-dated the peat formation. The best estimate of the age of this margin would be between 12.2 and 13.0 ka. On the inner Scotian Shelf the age of the Chignecto Phase margin was bracketed between 12.7 and 14 ka, based on sequence stratigraphy, age dates, and foraminiferal assemblages of a proglacial glaciomarine section. Combining both areas, a reasonable estimate for the time of formation of the Chignecto Phase margin is between 12.7 and 13 ka.

What caused the Chignecto Phase? Drawdown may only be part of the answer as the Chignecto Phase centres were located at or near ice streams of the previous Scotian Phase. Studies off the Scotian Slope have revealed a significant cooling and ice rafting event ca. 13 ka which may have resulted from renewed ice stream activity in the Gulf of St. Lawrence. It is possible that this event fits into a 1500 year millennial oscillation cycle, defined by Bond (1997), in which the next major event was the Younger Dryas.

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[1] Presented at the annual meeting of the Canadian Quaternary Association, Calgary, Alberta 1999

Using Whole Rock Geochemistry to Locate the Source of Igneous Erratics from Drumlins on the Atlantic Coast of Nova Scotia[1]

R. R. Stea and G. Pe-Piper[2]

Whole rock geochemistry has been determined for erratics from the surface Lawrencetown Till in two drumlins on the Atlantic coast of Nova Scotia. The geochemical data, particularly trace element composition, allows source rocks to be identified more precisely than by traditional petrographic microscopy. A drumlin near Lunenburg contains erratics of Neoproterozoic arc-related plutonic rocks and basalts that outcrop only in a small area near Parrsboro in the Cobequid Highlands. Some associated erratics of granite precisely match a small late Devonian pluton in the same area and other granites and rhyolite could also be derived from late Devonian rocks in the same area. The type section of the Lawrencetown Till contains different Neoproterozoic plutonic rocks of a type found in the eastern Cobequid Highlands, together with a distinctive late Devonian granite with sodic amphiboles that is restricted to a small area near the Debert River. Both these source areas indicate a southward flow of ice (Escuminac Phase) depositing the Lawrencetown Till, in contrast to earlier southeastward-flowing ice (Caledonia Phase) which deposited the Hartlen Till that forms the core of the drumlin. Drumlins in Nova Scotia are complex palimpsest landforms which formed by till-accretion, and evolved in surface form throughout multiple flow events.

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[1] In *Boreas*, v. 28, p. 308-328.

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Preliminary Geological Map of the Digby Area, Nova Scotia[1]

Chris White[2], Rick Horne[2], Catherine Muir[2] and James Hunter[2]

Lower to middle Palaeozoic units in the Digby area, southwest Nova Scotia, include the Goldenville and Halifax formations of the Meguma Group and the overlying White Rock and Torbrook formations. The Goldenville Formation consists of metasandstone with lesser, although variable amounts of, slate and metasiltstone. The Halifax Formation has been subdivided into three members, including (from bottom to top); (1) the Bloomfield member, consisting of distinct maroon and green (locally variegated), laminated metasiltstone; (2) the Acacia Brook member, consisting grey laminated metasiltstone and; (3) the Bear River member, consisting of slate and silty slate characterized by thin cross-laminated metasiltstone. This unit typically has abundant trace fossils and local graptolites. The White Rock Formation consists of cleaved, dark, silty slate, similar to the Bear River member, and local thick (25-30 m) quartzite beds. Trace fossils are common. An apparent disconformity or angular unconformity occurs with the underlying Halifax Formation. The Torbrook Formation conformably overlies the White Rock Formation and consists of mainly dark silty, locally fossiliferous shale, black siltstone and minor ironstone. The Lower to middle Palaeozoic rocks are cut by abundant mafic sills, including early (syndepositional?) fine-grained folded sills restricted to the Halifax Formation, gabbroic sills that post-date the Halifax Formation but predate the South Mountain Batholith, and younger undeformed sills related to the North Mountain Formation.

Lower to middle Palaeozoic units are folded into regional, northeast-trending F_1 folds; however, at a regional scale these units systematically young to the east with no map-scale repetition of units. This implies a regional-scale monocline with the Goldenville Formation and Bloomfield and Acacia Brook members defining an east-dipping limb in the west, the Bear River member representing a shallow limb in the central part, and the White Rock and Torbrook formations forming an east-dipping limb in the east. Post F_1 deformation includes kink folds throughout the area and crenulation cleavage developed in the west part of the area, particularly within the Acacia Brook and Bloomfield units. Several minor steep north- to northwest-trending faults cut the area.

The ca. 370 Ma South Mountain Batholith and Ellison Lake Pluton intruded the Lower to middle Palaeozoic units and produced contact metamorphic aureoles characterized by hornfels with cordierite, biotite and andalusite porphyroblasts.

To the north a conformable sequence of Triassic to Jurassic sedimentary rocks (Wolfville and Blomidon formations) and basalt (North Mountain Formation) unconformably overlie the older units.

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[1] *in* Atlantic Geoscience Society, Annual Colloquium, Amherst, Nova Scotia; Atlantic Geology, v. 35, no. 1, p. 105-106.

[2] Nova Scotia Department of Natural Resources, P. O. Box 698, Halifax, Nova Scotia B3J 2T9, Canada

Appendix 1

Mining Industry Activity in Nova Scotia, 1998

Mining Industry Expenditures

Investment by the mining industry in Nova Scotia is monitored by means of annual surveys of all companies having operations or activity in the province. Aggregate producers are not included in this survey. The surveys are carried out by the Nova Scotia Department of Natural Resources (DNR) jointly with Natural Resources Canada (Minerals and Metals Sector - Minerals and Mining Statistics Division), and Statistics Canada (Investment and Capital Stock Division). The Mines and Energy Development Division of DNR actively participates in the Annual Survey of Canadian Mineral Exploration Expenditures and the Annual Survey on Exploration Development, Capital and Repair Expenditures.

Preliminary figures indicate exploration expenditures in 1998 were down moderately from 1997 (Table 1.1), as was diamond-drilling. Capital expenditures at existing mines were down moderately in 1998 from 1997 while repair and maintenance expenditures were up moderately.

Mining Leases

There was one Mining Lease during the year. In November, Lynx Minerals Inc. was issued a Mining Lease for claims held over the Scotsville barite deposit in Inverness County. A Mining Lease renewal was also issued in September to Shaw Group Limited for silica at Nine Mile River, Hants County.

Mining Permits

The department issued one Mining Permit during the year. Tangier Limited Partnership was issued a Mining Permit to permit the extraction of gold and associated minerals at Tangier, Halifax County.

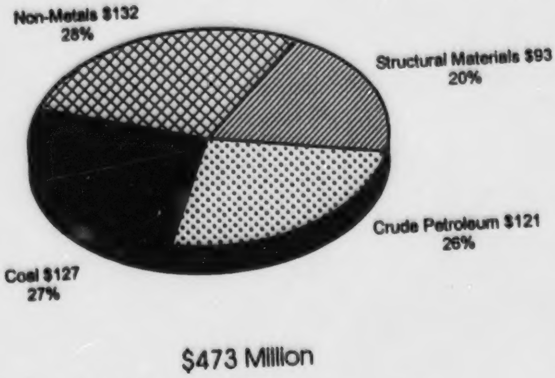
Production Information from Mines, Quarries and Other Operations

In 1998, the estimated total value of Nova Scotia's mineral production, including secondary mineral processing and crude petroleum, totalled $473 million (Fig. 1.1), a decrease of 10% from the year before. Excluding petroleum, the total value of Nova Scotia's mineral production totalled $352 million, down 14% from 1997's figure of $407 million. This decrease was due largely to lower outputs of salt, coal and construction aggregates. Employment in Nova Scotia's mineral industry totalled roughly 3700 persons (Fig. 1.2), a 3% decrease from the year before (Fig. 1.3).

Table 1.1. Mining industry expenditures in 1997 and 1998.

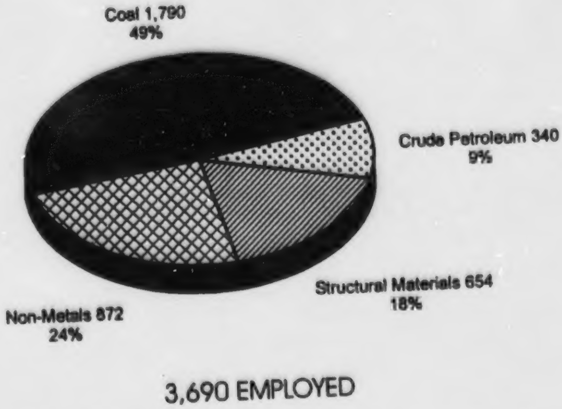
	1997	1998[1]
Mineral Exploration Expenditures (field plus overhead)2	$6,726,000	$4,835,000
Exploration diamond-drilling[2]	26 487 m	20 964 m
Exploration drilling - other[2]	1 440 m	879 m
Mineral Development Expenditures (field plus overhead)	$5,483,000	$2,713,000
Capital and Repair Expenditures at Mining Establishments		
Capital Expenditures	$33,927,505	$27,604,870
Repair and Maintenance Expenditures	$25,048,754	$ 35,415,668

[1] preliminary
[2] includes deposit appraisal



Metals too small to be expressed
Includes secondary mineral processing where applicable

Figure 1.1. Value of mineral production by commodity group.



Metals too small to be expressed
Includes secondary mineral processing employment where applicable
Numbers may not add to totals due to rounding

Figure 1.2. Employment by mineral commodity group.

Coal sales dropped by approximately 22% in 1998 to 2.1 million tonnes from 1997's figure of 2.7 million tonnes as production problems continued to plague the province's largest coal mine, the Cape Breton Development Corporation's Phalen Colliery. A number of major roof falls during the year resulted in significant work stoppage and layoffs, and forced their primary customer, Nova Scotia Power Inc., to again import coal from the United States.

There were mixed results for Nova Scotia's industrial mineral producers in 1998. Although down slightly from the year before, 1998 was another good year for Nova Scotia gypsum shipments with a total of 6.8 million tonnes shipped, mainly to wallboard plants along the U.S. Eastern Seaboard. Nova Scotia is Canada's largest gypsum producer, accounting for more than 80% of the country's total production. More than 70% of the total gypsum imports into the U.S. came from Nova Scotia in 1998.

Demand for Nova Scotia salt declined by 28% in 1998 from 1997 primarily due to the re-activation in the fall of 1997 of Seleine Mines Inc.'s salt mine located on the Magdelen Islands. Seleine was forced to suspend operations there due to severe flooding in 1995. Both the Seleine mine and Nova Scotia's Canadian Salt Company Limited mine are owned by the same parent company.

Cement sales were up 11% from 1997. Overall, aggregate production (crushed stone, sand and gravel) decreased by 11% in 1998 from the year before. Crushed stone production declined by 7% while sand and gravel production dropped by 20%. Peat moss production rose 33% in 1998 over 1997 as a new producer, MacDonald Peat Moss Limited, commenced production on a bog located near Kennetcook, Hants County. Clay products production was up 5% over 1997.

Although petroleum is included in the overall value of Nova Scotia's mineral production, this appendix focuses on the non-petroleum sectors of the industry (Table 1.2), providing a description of each mine site. Tables 1.3 to 1.6 provide more detailed information on production of different commodities. Site locations are shown on the accompanying maps, Figures 1.4 and 1.5. Production data are for the calendar year 1 January 1998 to 31 December 1998.

Metal Mines and Gold Mines

Metal Mines

There were no producing metal mines in 1998.

Gold Mines

TANGIER LIMITED PARTNERSHIP

Manager:	Peter Atkinson, General Manager
Address:	P. O. Box 8 Tangier, N. S. B0J 3H0
Production:	49 troy oz. (1524 g)
Employees:	35

In 1998, Tangier Limited Partnership re-activated underground mining operations at the Tangier site. During the months of November and December, 309 tonnes of ore were mined from the Whin vein.

Table 1.2. Summary of Nova Scotia mineral production, 1997 and 1998.

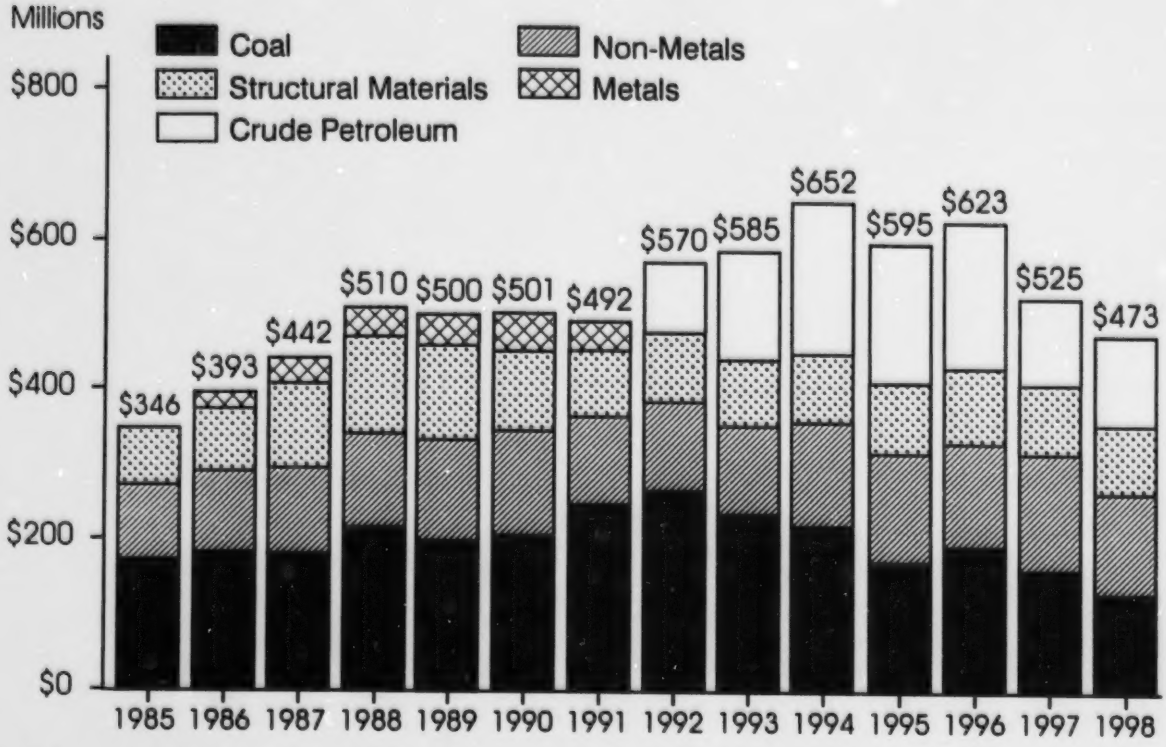
	1997		1998	
DESCRIPTION	**VALUE '000$[1]**	**EMPLOYMENT***	**VALUE '000$[1]**	**EMPLOYMENT***
METALS				
Gold	0[2]		21	
Total metals	0[2]		21	35
INDUSTRIAL MINERALS				
(Non-Metals)				
Anhydrite	2,148		1,733	
Barite	**731		**751	
Gypsum[3]	72,655		71,703	
Limestone[4] and Dolomite	4,776		2,824	
Peat	**1,491		**1,713	
Salt	**68,680		**51,241	
Silica	**2,600		**2,400	
Total Non-Metals	153,081	867	132,365	872
(Structural Materials)				
Dimension Stone	303		305	
Cement	**32,260		**35,065	
Clay Products	**5,000		**5,600	
Crushed Stone	43,575		40,445	
Sand & Gravel	14,032		11,164	
Total Structural Materials	95,170	700	92,579	654
Total Industrial Minerals	248,251	1,570	224,944	1,526
FUELS				
Coal	158,949	1,868	127,142	1,790
Petroleum - Crude	117,450	340	120,830	340
Total Fuels	276,399	2,208	247,970	2,130
TOTAL MINERAL PRODUCTION	524,560	3,800	472,935	3,690
CHANGE FROM PREVIOUS YEAR	-16%	-5%	-10%	-3%

[1] Estimated from Department of Natural Resources sources
[2] There were no metal mines operating in 1997
[3] Does not include the value of gypsum quarried for plaster products
[4] Does not include the value of limestone quarried for cement production
* Average number of persons during production period
** Processed or manufactured value
Note: Production represents shipments; numbers may not add to totals due to rounding

Table 1.3. Coal production for the calendar year 1998.

COMPANY	MINE NAME	LOCATION	PRODUCTION TONS	PRODUCTION TONNES	TOTAL NUMBER EMPLOYED[1]	APPROX. $VALUE[2]
UNDERGROUND MINING						
Cape Breton Development Corp. (CBDC)	Prince Mine	Point Aconi, Cape Breton County				
	Phalen Mine	Lingan, Cape Breton County				
Total (underground)			1,888,099	1 712 872	1,658	
OPEN PIT MINING						
Brogan Mining Company Limited	Sullivan Creek and Toronto Rd. Mines	Sullivan Creek, Cape Breton County	48,232	43 756	20	
Cape Crushing Company Limited	Merritt Point Mine	North Sydney, Cape Breton County	2,646	2 400	2	
Evans Coal Mines Limited	St. Rose Mine	St. Rose, Inverness County	106,134	96 284	32	
Pioneer Coal Limited	Stellarton Mine	Stellarton, Pictou County	243,157	220 591	58	
Thorburn Mining Limited	Thorburn Mine	Thorburn, Pictou County	56,118	50 910	23	
Total (open pit)			456,287	413 941	135	
TOTAL FOR ALL COAL PRODUCERS			2,344,372	2 126 800	1,790	127,142,000

[1] personnel employed in clerical, supervisory, etc. positions as well as mining personnel
[2] estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding



Includes secondary mineral processing where applicable

Figure 1.3. Historical trend of the value of mineral production in Nova Scotia, 1985-1998.

Coal Mining Operations

During 1998, there were two underground coal mines and six surface coal mines operating in the province. Table 1.3 summarizes production information for the coal mines. The summaries below give brief details of the underground and surface coal mines operating in Nova Scotia.

Underground Coal Mines

CAPE BRETON DEVELOPMENT CORPORATION

Manager(s):	B. MacDonald, General Manager, Phalen Colliery T. Isaacs, General Manager, Prince Colliery
Address:	P. O. Box 2500 Sydney, N. S. B1P 6K9

Raw Coal
Production: 1,942,963 tons (1 762 645 tonnes)
Employees: 1,658

The Cape Breton Development Corporation is a federal Crown Corporation that operated two underground coal mines in Cape Breton County during 1998.

Phalen Colliery

Raw Coal
Production: 1,089,520 tons (988 406 tonnes)

The Phalen Colliery, near New Waterford, Cape Breton County, commenced production in 1987 in the Phalen Seam. The coal is extracted by the mechanical retreat longwall method. During the year, coal was mined from the No. 3 Center and No. 8 East longwall panels. A roof fall occurred on the main gate of 8 East wall in September 1998, haulting production for six weeks.

Prince Mine

Raw Coal
Production: 853,444 tons (774 239 tonnes)

Table 1.4. Industrial minerals production for the calendar year 1998.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROXIMATE $VALUE[2]
		TONS	TONNES		
GYPSUM					
Fundy Gypsum Company	Miller Creek and Wentworth Road, Hants County	1,839,417	1 668 708	166	
Georgia-Pacific Canada, Inc.	Sugar Camp, Inverness County	1,343,143	1 218 491	98	
Little Narrows Gypsum Company	Little Narrows, Victoria County	1,090,597	989 383	104	
National Gypsum (Canada) Limited	East Milford, Halifax County	3,254,286	2 952 269	100	
Total (gypsum)		7,527,500	6 828 000	468	71,703,000
ANHYDRITE					
Fundy Gypsum Company	Miller Creek and Wentworth Road, Hants County	69,499	63 049	see gypsum	
Little Narrows Gypsum Company	Little Narrows, Victoria County	84,562	76 714	see gypsum	
Total (anhydrite)		154,100	139 800		1,733,000
SALT					
The Canadian Salt Company Limited	Pugwash, Cumberland County	836,351	758 733	210	
Sifto Canada Inc.	Nappan, Cumberland County	97,810	88 733	73	
Total (salt)		934,166	847 470	283	51,241,000[3]
LIMESTONE AND DOLOMITE					
Lafarge Canada Inc.	Brookfield, Colchester County	543,434	493 000	11	
Mosher Limestone Company Limited	Upper Musquodoboit, Halifax County	80,328	72 873	17	
Nova Scotia Power Incorporated	Glen Morrison, Cape Breton County	98,847	89 673	14	
Ridge Brokers Limited	Southside Harbour, Antigonish County	5,989	5 433	1	
Scotia Limestone Limited	Kellys Cove, Victoria County	12,114	10 990	3	
Total (limestone and dolomite)		740,711	671 969	46	2,824,000[4]
BARITE					
E-Z-EM Canada Inc.	Brookfield, Colchester County	659	598	16	751,500[3]
Total (barite)		659	598	16	751,500[3]
CLAY					
Shaw Brick (a member of the Shaw Group Limited)	Lantz, Hants County Shubenacadie, Halifax County	18,199	16 510	See clay products	0[5]
SHALE					
Shaw Brick (a member of the Shaw Group Limited)	Milford, Hants County New Glasgow, Pictou County	7,800	7 076	See clay products	0[5]
Total (clay and shale)		25,999	23 586	See clay products	0[5]

Table 1.4. Continued.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROXIMATE $VALUE[2]
		TONS	TONNES		
SILICA SAND					
Shaw Resources (a member of the Shaw Group Limited)	Nine Mile River, Hants County	61,729	56 000	6	2,400,000
Total (silica sand)		61,729	56 000	6	2,400,000
DIMENSION STONE					
Heritage Memorials Ltd.[2]	Quarry: Nictaux, Annapolis County (granite) Plant: Windsor, Hants County	1,854	1 682	20	
Wallace Quarries Ltd.	Quarry: Wallace, (Sandstone) Cumberland County	448	406	5	
Total (dimension stone)		2,302	2 088	25	305,000
PEAT MOSS					
Annapolis Valley Peat Moss Company[2]	Berwick, Kings County	4,507	4 089	20	
Clare Organic Products Ltd.[2]	Meteghan Station, Digby County	3,900	3 538	15	
McDonald Peat Moss Limited[2]	Kennetcook, Hants County	1,752	1 589	18	
Total (peat moss)		8,407	9 216	53	1,712,500
AGGREGATES					
Crushed Stone	Various	8,916,505	8 089 000	354	40,445,000
Sand and Gravel	Various	3,076,500	2 791 000	153	11,164,000
Total (aggregates)		11,993,000	10 880 000	507	51,609,000
TOTAL FOR INDUSTRIAL MINERALS[6]		21,449,000	19 458 000	1,400	184,279,000

[1] total employees: mining, production, clerical, supervisory, etc.
[2] estimate from Nova Scotia Department of Natural Resources sources
[3] processed or manufactured value
[4] does not include the value of Lafarge Canada Inc. production which value is transferred to the higher manufacturered value (cement)
[5] value assigned to the higher manufactured valuation (bricks)
[6] excluding secondary mineral manufacturing (Table 1.7)
Note: production represents shipments; numbers may not add to totals due to rounding

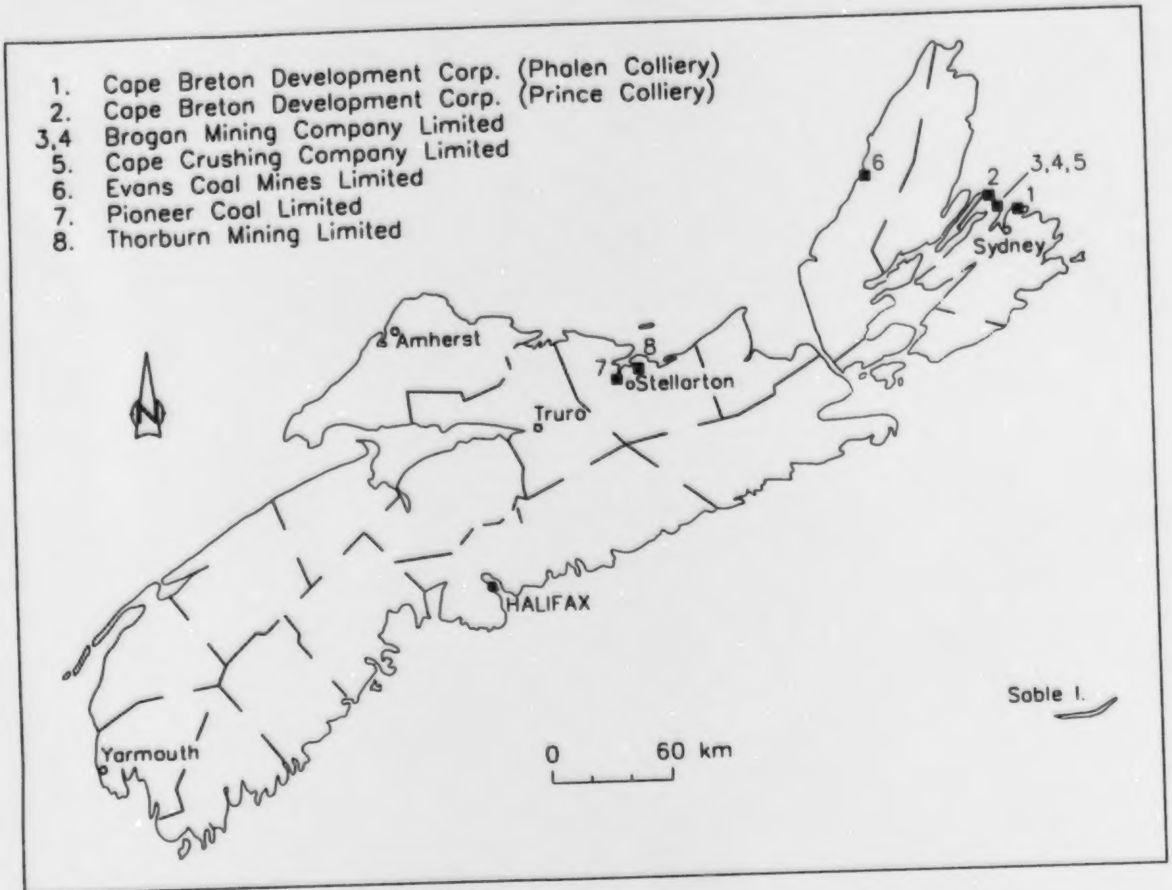

1. Cape Breton Development Corp. (Phalen Colliery)
2. Cape Breton Development Corp. (Prince Colliery)
3,4 Brogan Mining Company Limited
5. Cape Crushing Company Limited
6. Evans Coal Mines Limited
7. Pioneer Coal Limited
8. Thorburn Mining Limited
6
2
3,4,5
1
Sydney
Amherst
8
7
Stellarton
Truro
HALIFAX
Sable I.
Yarmouth
0
60 km

Figure 1.4. Location of coal mines in Nova Scotia.

The Prince Mine is located in Point Aconi, Cape Breton County. The mine began underground production from the Hub Seam in 1975, initially using room and pillar methods. Mechanized retreat longwall operations began in 1980.

During 1998, coal was mined from the No. 15 West and No. 9 East longwall panels. Development work continued on the No. 1 North longwall panel.

Surface Coal Mines

EVANS COAL MINES LIMITED

Manager:	E. Fraser
Address:	R. R. #1 Inverness, N. S. B0E 1N0
Production:	106,134 tons (96 284 tonnes) of coal
Employees:	32

The Evans Coal Mines Limited began surface coal mining operations at St. Rose, Inverness County, in 1993, following the closure of the underground mine in 1992. Coal is extracted from the No. 5 Seam crown pillar and from the pillars left behind by the underground operation. Mining proceeded in a southerly direction. Overburden and waste rock were removed by blasting and ripping by bulldozers. Material is loaded and hauled using hydraulic excavators and dump trucks. Extensive underground workings were encountered during the coal extraction process. During the year, the Duggan Mountain Road was reinstated to its original location upon completion of mining and reclamation in the area.

PIONEER COAL LIMITED

Manager:	C. Chisholm
Address:	P. O. Box 929 Westville, N. S. B0K 2A0
Production:	243,157 tons (220 591 tonnes) of coal
Employees:	58

Table 1.5. Secondary mineral manufacturing for the calendar year 1998.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[1]	APPROX. SVALUE[2]
		TONS	TONNES		
CLAY PRODUCTS					
Shaw Brick (a member of the Shaw Group Limited)	Lantz, Hants County	26,000	23 587	45	5,600,000
PORTLAND CEMENT					
Lafarge Canada Inc.	Brookfield, Colchester County	324,076	294 000	77	35,065,000
TOTAL FOR SECONDARY MINERAL MANUFACTURING				122	40,665,000

[1] total number of employees including office, clerical, supervisory, mining and production
[2] estimated from Nova Scotia Department of Natural Resources sources
NOTE: Production represents shipments; numbers may not add to totals due to rounding

Table 1.6. Metallic mineral production for the calendar year 1998.

COMPANY	LOCATION	PRODUCTION		TOTAL NUMBER EMPLOYED[2]	APPROXIMATE VALUE[3] ($)
GOLD					
Tangier Limited Partnership[1]	Tangier, Halifax County	49 troy ozs.	1524 g	35	21,400
TOTAL FOR METALLIC MINERAL PRODUCTION				35	21,400

[1] operated for part of year only.
[2] total number of employees including office, clerical, supervisory, mining and production.
[3] value based on average annual metal price times weight. Also includes value of approximately 2 troy ozs. of bi-product silver.
Note: Production represents shipments; sum of components may not add to totals due to rounding.

Pioneer Coal began mining coal from the Foord Seam at the Stellarton mine site in March 1996, using hydraulic excavators and dump trucks. The seam was mined in both an easterly and westerly direction from the existing pit. The Foord Seam is approximately 40 feet thick. Mining becomes more selective in the western end of the mine as the percentage of ash increases. The company conducted mining operations at the site from March to June and September to December.

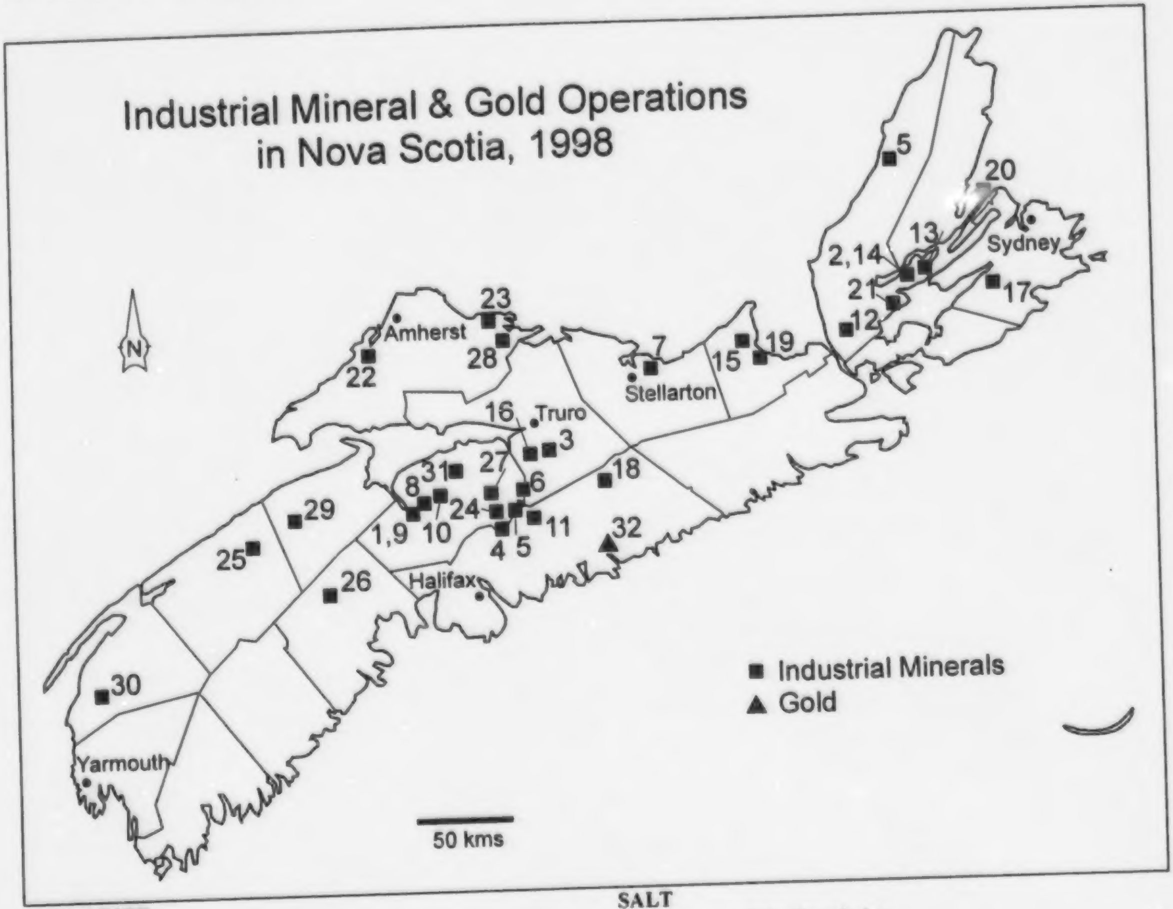
The coal mined from the Stellarton operation was blended on-site with coal trucked from the Evans Coal Mine and the Thorburn Mine before being shipped to the Trenton generating station.

THORBURN MINING LIMITED

Manager: C. Chisholm
Address: P. O. Box 929
Westville, N. S. B0K 2A0
Production: 56,118 tons (50 910 tonnes) of coal
Employees: 23

Mining at the Thorburn site began in June 1995. In 1998, the mine operated in January, February, June to October inclusive and December.

Coal was extracted from the McBean Seam crown pillar and from pillars remaining from the former underground mining operations. During the year,



ANHYDRITE
1. Fundy Gypsum Co.
2. Little Narrows Gypsum Co.

BARITE
3. E-Z-EM Canada Inc.

CLAY AND SHALE
4-7. Shaw Brick, a member of the Shaw Group Limited

GYPSUM
8-9. Fundy Gypsum Co
10. National Gypsum (Canada) Ltd.
11. Georgia-Pacific Corp.
12-13. Little Narrows Gypsum Co. Ltd.
14. Tusket Mining Incorporated

LIMESTONE AND DOLOMITE
15. Lafarge Canada Inc.
16. Nova Scotia Power, Inc.
17. Mosher Limestone Co. Ltd.
18. Ridge Brokers Ltd.
19. Scotia Limestone Ltd.
20. Shaw Resources, a member of the Shaw Group Limited

SALT
21. Sifto Canada Inc.
22. The Canadian Salt Co. Ltd.

SILICA SAND
23. Shaw Resources, a member of the Shaw Group Limited

DIMENSION STONE
24. Heritage Memorials Ltd.
25. Lange Natural Rock and Stone Supplies
26. Scotia Slate Products Ltd.
27. Wallace Quarries Ltd.

PEAT MOSS
28. Annapolis Valley Peat Moss Co.
29. Clare Organic Products Limited
30. MacDonald Peat Moss Limited

GOLD
31. Tangier Limited Partnership

Figure 1.5. Location of industrial mineral and gold operations in Nova Scotia, 1998.

overburden and waste rock were removed by ripping with bulldozers. Material was loaded and hauled using hydraulic excavators and dump trucks. The seam varies in thickness from 4 to 7 feet.

CAPE CRUSHING COMPANY LIMITED

Manager: E. Brogan
Address: P. O. Box 265
North Sydney, N. S. B2A 3M3
Production: 2,646 tons (2 400 tonnes) of coal
Employees: 2

The company operates a small surface coal mine at Alder Point, Cape Breton County. Coal was mined during the year from the Upper and Lower Bonar Seams using small scale excavating equipment.

BROGAN MINING COMPANY LIMITED

Manager: R. Brogan
Address: 126 Main Street
North Sydney, N. S. B1V 2L6
Production: 48,232 tons (43 756 tonnes) of coal
Employees: 20

During the year, Brogan Mining Limited completed surface mining operating at the Toronto Road mine site. Coal was recovered from both the Sydney Main and Stubbert coal seams. The coal was blended with coal mined from a bulk sample extracted from the Little Pond area. Mining is carried out using bulldozers, hydraulic excavators and dump trucks. The company conducted progressive reclamation of the mined areas during the year.

The company also operated a surface coal mine at Sullivans Creek, Cape Breton County, during 1998. Coal from both operations was blended to produce a saleable product.

BLACK GOLD ENTERPRISES LIMITED

Manager: M. McCormick
Address: R. R. #1
Springhill, N. S. B0M 1X0
Production: 0
Employees: 0

There was no production at the mine in 1998.

Industrial Minerals Mining

Gypsum and Anhydrite

GEORGIA-PACIFIC CANADA INCORPORATED

Manager: D. Duncan
Address: P. O. Box 400
Port Hawksbury, N. S. B0E 2V0
Production: 0 tons (0 tonnes) of gypsum
Employees: 0

There was no production at the MacKay Settlement mine in 1998.

FUNDY GYPSUM COMPANY

Manager: B. MacMillon
Address: P. O. Box 400
Windsor, N. S. B0N 2T0
Production: 69,499 tons (63 049 tonnes) of anhydrite
1,839,417 tons (1 668 708 tonnes) of gypsum
Employees: 166

The Fundy Gypsum Company operates quarries and crushing plants in the Wentworth Road and Miller Creek areas near Windsor, Hants County. In 1998, the company produced gypsum from its Miller Creek quarry and both gypsum and anhydrite from the Wentworth quarry. The Wentworth ore is processed in the company's heavy media plant to separate anhydrite from gypsum.

The gypsum and anhydrite are transported by unit train to ship-loading facilities at Hantsport, a distance of 19 km. These products are transported to wallboard and cement plants in the United States.

GEORGIA-PACIFIC CANADA INC.
Manager: R. L. Fraser
Address: P. O. Box 400
Port Hawksbury, N. S. B0E 2V0
Production: 1,343,143 tons (1 218 491 tonnes) of gypsum
Employees: 98

Georgia-Pacific Corporation operates a gypsum quarry at Sugar Camp, Inverness County. Overburden at the site is removed using a dragline and truck and shovels. The gypsum is drilled and blasted prior to being transported to the crusher by trucks. The crushed gypsum is then transported by truck to ship loading facilities at Point Tupper, Richmond County, a distance of 19 km.

LITTLE NARROWS GYPSUM COMPANY

Manager: Bruce Allan
Address: R. R. #1
Little Narrows, N. S. B0E 1T0
Production: 63,049 tons (76 714 tonnes) of anhydrite
1,090,597 tons (989 383 tonnes) of gypsum
Employees: 104

Little Narrows Gypsum Company Limited operates two gypsum quarries and one anhydrite quarry near Little Narrows, Victoria County. All the gypsum and anhydrite produced is shipped from the company's dock on the Bras d'Or Lakes to destinations in Canada and the United States.

NATIONAL GYPSUM (CANADA) LIMITED

Manager: Pat Mills
Address: P. O. Box 57
Milford, N. S. B0N 1Y0
Production: 3,254,286 tons (2 952 269 tonnes)
Employees: 100

National Gypsum (Canada) Limited operates the largest gypsum quarry in the province at East Milford, Halifax County. The gypsum is drilled and blasted and loaded onto trucks with hydraulic excavators and loaders. The gypsum is then transported by unit train from Milford to Wright's Cove, Dartmouth, a distance of 45 km, where it is loaded onto ships for points in Canada and the United States.

TUSKET MINING INCORPORATED

Manager: C. E. Bain
Address: P. O. Box 48100
Bedford, N. S. B4A 3Z2
Production: 0 tons (0 tonnes)

Production in 1998 was limited to a 10 000 tonne sample at the Murchyville Mine, Halifax County. There was no product shipped in 1998.

Salt

THE CANADIAN SALT COMPANY LIMITED

Manager: A. Davidson
Address: P. O. Box 160
Pugwash, N. S. B0K 1L0
Production: 836,351 tons (758 733 tonnes) of salt
Employees: 210

The Canadian Salt Company Limited mine is located at Pugwash, Cumberland County. The salt is mined by a room and pillar system of extraction, using diesel and electric drills, undercutters, loaders and trucks. Primary production during the year was from the 1000 foot level. Secondary production was from the 730 foot level and the 830 foot level.

The processing plant at the site produces industrial grades of salt, salt blocks for farm use, and refined salt for domestic consumption. Transportation is either by road, rail or from the company owned ship-loading facility at Pugwash.

SIFTO CANADA INCORPORATED

Manager: D. Dickie
Address: P. O. Box 550
Amherst, N. S. B4H 4A1
Production: 97,810 tons (88 733 tonnes) of salt
Employees: 73

Salt has been produced from a solution salt mine at Nappan, Cumberland County, since 1947. Salt is mined by pumping water into underground wells where the salt is dissolved by the water and the resulting brine solution is then pumped back to the surface. The salt is then recovered from the brine in a processing plant, using a 'mechanical vapour recompression evaporating process' system.

During the year, salt was produced from the No. 7 and No. 8 brine wells.

Barite

E-Z-EM CANADA INCORPORATED, NYSTONE DIVISION

Manager: V. Prostak
Address: P. O. Box 69
Debert, N. S. B0M 1G0
Production: 659 tons (598 tonnes) of pharmaceutical grade barite
Employees: 16

The barite deposit is located 1.6 km northeast of Brookfield, Colchester County. During 1997, the surface mine was dewatered and approximately 5,425 tons of ore were mined from the pit. All of the material that had previously been mined and stockpiled at the mine was trucked to the company's plant at Debert where it was upgraded to a pharmaceutical quality product. Refined products are then transported to the parent company, E-Z-EM Corporation, New York, USA, for further processing and packaging.

Limestone and Dolomite

LAFARGE CANADA INC.

Manager: J. Cross
Address: P. O. Box 5
Brookfield, N. S. B0N 1C0
Production: 543,434 tons (493 000 tonnes) of limestone
Employees: 11 (quarry) 77 (cement plant)

Lafarge Canada Inc. operates a limestone quarry at their Brookfield cement manufacturing plant, located 5 km west of Brookfield. The total production from the quarry is used to produce cement.

MOSHER LIMESTONE COMPANY LIMITED

Manager: D. Mosher
Address: P. O. Box 28
Upper Musquodoboit, N. S.
B0N 2M0
Production: 80,328 tons (72 873 tonnes) of limestone
Employees: 17

Mosher Limestone operates quarries near Upper Musquodoboit, Halifax County. The company produces agricultural grade dolomitic limestone in its grinding plant at Upper Musquodoboit. The product is bagged or supplied in bulk for distribution throughout the Atlantic Provinces. In 1996, the company began producing a pelletized limestone product for the domestic garden market.

SHAW RESOURCES, A MEMBER OF THE SHAW GROUP LIMITED

Manager: K. Hardie
Address: P. O. Box 60
Shubenacadie, N. S. B0N 2H0
Production: 0 tons (0 tonnes) of marble

Shaw Resources produces marble intermittently from a quarry at Marble Mountain, Inverness County. This marble is used for brick manufacture and in landscaping.

RIDGE BROKERS LIMITED

Manager: A. Alward
Address: P. O. Box 59
Havelock, N. B. E0A 1W0
Production: 5,989 tons (5 433 tonnes) of limestone
Employees: 1

The company operates a small quarry at Southside, Antigonish Harbour, Antigonish County. No mining took place at the site in 1998. Production came from existing inventory.

SCOTIA LIMESTONE LIMITED

Manager: D. Mosher
Address: P. O. Box 28
Upper Musquodoboit, N. S. B0N 2M0
Production: 12,114 tons (10 990 tonnes) of dolomite
Employees: 3

In 1996, Mosher Limestone Company Limited purchased the assets of the Kellys Cove dolomite quarry from Scotia Limestone. The mine produced an agricultural grade dolomite for domestic sale as well as a product for the offshore steel industry. No mining took place at the site during 1998; all production came from existing inventory.

NOVA SCOTIA POWER INCORPORATED
(OPERATED BY KELLY ROCK LIMITED)

Manager: D. MacKenna
Address: P. O. Box 1206
Sydney, N. S. B1P 6J9
Production: 98,847 tons (89 673 tonnes) of limestone
Employees: 17

The limestone quarry at Glen Morrison, Cape Breton County, began production in 1993. The company produces several products at the on-site milling facility. In 1996, the company completed construction of a secondary and tertiary processing plant and a large limestone storage facility. During 1998, most of the production from this site was shipped to Point Aconi for use in the fluidized bed power generating station.

Clay

SHAW BRICK, A MEMBER OF THE SHAW GROUP LIMITED

Manager: B. Frizzell
Address: P. O. Box 2130
Lantz, N. S. B0N 1R0
Production: 25,999 tons (23 586 tonnes) of clay & shale
Employees: 4

Shaw Brick mines clay from pits at Lantz, Milford and Shubenacadie, all in Hants County, and shale from quarries located in Hardwood Lands, Hants County, and New Glasgow, Pictou County. These materials are used in the company's plant in Lantz for the manufacture of bricks and other structural clay products.

Silica Sand

SHAW RESOURCES, A MEMBER OF THE SHAW GROUP LIMITED

Manager: K. Hardie
Address: P. O. Box 60
Shubenacadie, N. S. B0N 2H0
Production: 61,729 tons (56 000 tonnes) of silica sand
Employees: 6

Shaw Resources produces silica sand from a deposit at West Indian Road, Hants County. This sand is processed into several silica sand products including glass grade sand.

Dimension Stone

HERITAGE MEMORIALS LIMITED

Manager: G. Nelson
Address: P. O. Box 308
Windsor, N. S. B0N 2T0
Production: 1,854 tons (1 682 tonnes) of granite (estimated)
Employees: 20

The company periodically operates a small quarry at Nictaux West, Annapolis County. The grey granite is used as dimension stone at the company's memorial manufacturing plant at Windsor, Hants County.

WALLACE QUARRIES LIMITED

Manager: S. Flynn
Address: P. O. Box 203
Wallace, N. S. B0K 1Y0
Production: 448 tons (406 tonnes) of building stone
Employees: 5

The Wallace Quarries, located near Wallace, Cumberland County, continued to supply building stone for major building rehabilitation work in Halifax and central Canada. Blocks of stone are sent for cutting to processing facilities in Nova Scotia, New Brunswick and Quebec to supply local markets.

OTHER

Two other stone operations, for which production information was not available at the time of publication, were Scotia State Products Ltd. and Lange Natural Rock and Stone Supplies. Scotia Slate operates a small slate quarry near East Gore, Hants County, while Lange operates a small granite quarry near Parkdale, Lunenburg County.

Peat Moss

ANNAPOLIS VALLEY PEAT MOSS COMPANY LIMITED

President: H. Endres
Address: Berwick, N. S. B0P 1E0
Production: 4,507 tons (4 089 tonnes) of peat moss (estimated)
Employees: 20 (some part time)

The company uses vacuum harvesters to recover agricultural peat from a 500 acre (200 ha) bog located near Berwick, Kings County. Baled peat products are shipped to markets in Canada, the United States and Japan.

CLARE ORGANIC PRODUCTS LIMITED

Owner: Gerald Thimot
Address Box 174-A, Saulnierville
Digby County, N. S. B0W 2Z0
Production: 3,900 tons (3 538 tonnes) of peat moss (estimated)
Employees: 15 (some part time)

The company, which uses vacuum harvesters to recover agricultural peat from a 200 acre (81 ha) bog located near Meteghan Station, Digby County. The company has a contract to supply a major Maritime peat producer with baled peat destined for international markets.

MACDONALD PEAT MOSS LIMITED

Owner: Lameque Quality Group Ltd.
Address 86 Tourbe Street
Lameque, N. B. E8T 1A3
Production: 1,752 tons (1 589 tonnes) of peat moss (estimated)
Employees: 18

MacDonald Peat Moss Limited, a wholly-owned subsidiary of New Brunswick's Lameque Quality Group Ltd., has lease rights to a 1700 acre (688 ha) peat bog located on Crown land, approximately 12 km west of Kennetcook, Hants County. 1998 was the first year of production for the company, which exports baled peat to international markets.

Aggregate Resources

Approximately 11 million tonnes of construction aggregates were produced in Nova Scotia in 1998. Twenty-four companies reported crushed stone production totalling 8.1 million tonnes while 47 producers reported sand and gravel production totalling 2.8 million tonnes. The majority of aggregate was consumed within the province, with approximately 2 million tonnes exported.

Two companies eclipsed the 1 million tonne mark for crushed stone production in 1998. Rocky Lake Quarry Limited of Bedford, Nova Scotia, reported shipments of 1.4 million tonnes while Martin Marietta Materials Canada Ltd. reported just over 2.0 million tonnes shipped. Martin Marietta's Porcupine Mountain operation was the country's seventh largest in 1998.

Appendix 2

Minerals and Energy Branch Geoscience Maps and Publications for Sale

BEDROCK GEOLOGY MAPS

Provincial Scale

1:2 000 000

Map ME 1979-5 to Map ME 1979-9 Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. **$1.00** (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)

1:1 000 000

OFM ME 1999-1 Index Map to Nova Scotia Department of Natural Resources Bedrock Geology, Surficial Geology and Aeromagnetic Open File Maps of Nova Scotia [scale 1:1 000 000], compiled by K. D. Fraser, 1999, 1 map. **$5.00**

1:640 000

Outside Publication ME 1989-1 Geological Highway Map of Nova Scotia, Second Edition, by Howard V. Donohoe, Jr., and R. G. Grantham, scale 1:640 000, 1989 (Atlantic Geoscience Society, Special Publication Number 1). **$3.50**

1:500 000

Map ME 2000-1 Geological Map of the Province of Nova Scotia, compiled by J. D. Keppie, 2000, scale 1:500 000. **$20.00**

Regional Scale

1:250 000

Map ME 1994-1 Geological Map of the South Mountain Batholith, Western Nova Scotia, compiled by M. A. MacDonald with contributions from M. C. Corey, L. J. Ham and R. J. Horne, 1994, scale 1:250 000. **$6.00**

1:125 000

Map ME 1983-4 Geological Map of the Red River Anorthosite Complex, Inverness and Victoria Counties, Nova Scotia, by P. K. Smith and A. S. Macdonald, scale 1:125 000. **$1.50**

Map ME 1978-1 Preliminary Geology Map of the Cobequid Highlands, by H. V. Donohoe and P. I. Wallace, scale 1:125 000, (Superseded by Map ME 1982-6, Map ME 1982-7, Map ME 1982-8, Map ME 1982-9, scale 1:50 000). **$3.50**

1:100 000

OFM ME 1998-1 Preliminary Geological Map of Guysborough, Richmond and Antigonish Counties (parts of NTS sheets 11E/08, 11F/05, 11F/06, 11F/10, 11F/11, 11F/12 and 11F/15, Nova Scotia, Canada, by C. E. White and S. M. Barr, 1998, 1 colour map, scale 1:100 000. **$5.00**

Map ME 1984-2 Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia, by Sandra M. Barr and Jeremy R. D. Setter, 1984, scale 1:100 000. **$4.00**

Detailed Scale

1:500 000

OFM ME 2000-3 Preliminary Geological Map of the Wolfville/Windsor Area, Hants and Kings Counties, Nova Scotia [21H/01 and Parts of 21A/16C and D], compiled by R. G. Moore, S. A. Ferguson, R. C. Boehner, C. M. Kennedy, 2000, 1 colour map, scale 1:50 000. **$5.00**

OFM ME 1999-3 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/15], Nova Scotia, by L. J. Ham, 1999, 1 colour map, scale 1:50 000. **$5.00**

OFM ME 1999-2 Geological Map of the Musquodoboit Batholith, Halifax County [part of NTS sheet 11D/14], Nova Scotia, by L. J. Ham, 1999, 1 colour map, scale 1:50 000. **$5.00**

Map ME 1996-1 Geological Map of the Shubenacadie and Musquodoboit Basins Showing the Extent of Early Cretaceous Sediments (part of NTS Map Sheet 11E/03), Colchester and Halifax Counties, Nova Scotia, by R. R. Stea, P. W. Finck, S. E. Pullan, and M. C. Corey, 1996, scale 1:50 000. **$6.00**

Map ME 1994-8 Geological Map of Bridgetown, Nova Scotia (NTS Sheet 21A/14): South Mountain Batholith Project, by M. A. MacDonald and L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-7 Geological Map of Digby, Nova Scotia (NTS Sheet 21A/12): South Mountain Batholith Project, by L. J. Ham, 1994, scale 1:50 000. **$6.00**

Map ME 1994-6 Geological Map of Milford, Nova Scotia (NTS Sheet 21A/11): South Mountain Batholith Project, by M. C. Corey and R. J. Horne, 1994, scale 1:50 000. **$6.00**

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Map ME 1994-3 Geological Map of Wentworth Lake (NTS Sheet 21A/04 and part of 20P/13): South Mountain Batholith Project, by L. J. Ham and M. A. MacDonald, 1994, scale 1:50 000. **$6.00**

Map ME 1994-2 Geological Map of Lake Rossignol, Nova Scotia (NTS Sheet 21A/03 West Half): South Mountain Batholith Project, by M. C. Corey and R. J. Horne, 1994, scale 1:50 000. **$6.00**

Map ME 1993-1 Geological Map of New Germany (NTS Sheet 21A/10), Nova Scotia, by R. J. Horne, 1992, scale 1:50 000. **$6.00**

Map ME 1992-1 Geological Map of Gaspereau Lake (NTS Sheet 21A/15 and part of 21H/02), Nova Scotia, by M. A. MacDonald and L. J. Ham, 1992, scale 1:50 000. **$6.00**

Map ME 1990-14 Cumberland Basin Geology Map, Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties, by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000. **$6.00**

Map ME 1990-13 Cumberland Basin Geology Map, Oxford and Pugwash, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. **$6.00**

Map ME 1990-12 Cumberland Basin Geology Map, Amherst, Springhill and Parrsboro, Cumberland County, by R. J. Ryan, R. C. Boehner, A. Deal and J. H. Calder, 1990, scale 1:50 000. **$6.00**

Map ME 1990-11 Cumberland Basin Geology Map, Apple River and Cape Chignecto, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. **$6.00**

Map ME 1990-10 Geological Map of Windsor (21A/16, West Half and part of 21H/01), Nova Scotia, by L. J. Ham, scale 1:50 000. **$6.00**

Map ME 1990-9 Geological Map of Chester (21A/09), Nova Scotia, by M. C. Corey, scale 1:50 000. **$7.00**

Map ME 1989-4 Geology of Mabou Highlands (NTS sheet 11K/03, west half), Nova Scotia, by S. M. Barr and A. S. Macdonald, 1989, colour map, scale 1:50 000 (accompanies Paper ME 1989-2). **$3.00**

Map ME 1987-8 Bedrock Geological Map of Mount Uniacke (11D/13 West), by M. C. Corey, 1987, scale 1:50 000. **$6.00**

Map ME 1987-7 Bedrock Geological Map of Windsor (21A/16 East), by L. J. Ham and R. J. Horne, 1987, scale 1:50 000. **$6.00**

Map ME 1987-6 Bedrock Geological Map of Halifax and Sambro (11D/12 and 11D/05), by M. A. MacDonald and R. J. Horne, 1987, scale 1:50 000. **$6.00**

Map ME 1986-1 Geological Map of the Sydney Basin, Cape Breton Island, Nova Scotia, by R. C. Boehner and P. S. Giles, 1986, scale 1:50 000. **$5.00**

Map ME 1985-2 Geological Map of the Loch Lomond Basin and Glengarry Half Graben, by R. C. Boehner and G. Prime, scale 1:50 000. **$5.00**

Map ME 1982-9 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Debert - Mt. Thom Region, Sheet 4 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. **$8.00 each, $25.00 set of Map ME 1982-6 to Map ME 1982-9**

Map ME 1982-8 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Economy River - Folly Lake Region, Sheet 3 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. **$8.00 each, $25.00 set of Map ME 1982-6 to Map ME 1982-9**

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Map ME 1982-6 Geological Map of the Cobequid Highlands, Colchester, Cumberland and Pictou Counties, Nova Scotia, Advocate Harbour - Port Granville Region, Sheet 1 of 4, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. **$8.00 each, $25.00 set of Map ME 1982-6 to Map ME 1982-9**

Map ME 1982-5 Geological Map of the Northern Antigonish Highlands, Nova Scotia, by J. B. Murphy, J. D. Keppie and A. Hynes, scale 1:50 000. **$4.00**

Map ME 1982-4 Geological Map of the Shubenacadie and Musquodoboit Basins, by P. S. Giles and R. C. Boehner, scale 1:50 000. **$5.00**

Map ME 1982-3 Geological Map of the Eureka Area, by P. S. Giles, scale 1:50 000. **$3.00**

Map ME 1982-2 Geological Map of the Antigonish Basin, by R. C. Boehner and P. S. Giles, scale 1:50 000. **$3.00**

1:31 680

Map ME 1967-3 Geology, Area of Christopher McLeod Brook, Victoria County, Nova Scotia, by G. C. Milligan, B. White, R. M. Creed and A. K. Chatterjee, 1967, colour map, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1967-2 Geology, Middle River Area, Inverness and Victoria Counties, Nova Scotia, by G. C. Milligan, B. White, R. M. Creed and A. K. Chatterjee, 1967, colour map, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1967-1 Geology, Crowdis Mountain Area, Victoria County, Nova Scotia, by G. C. Milligan, R. C. Parsons, B. White, R. M. Creed and A. K. Chatterjee, 1967, colour map, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1963-2 Geology, Boisdale Hills, Scotch Lake to Steeles Crossing, Cape Breton County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1963, colour map, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1963-1 Geological Map of the Craignish Hills, Inverness County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1963, colour map, scale 1:31 680 (accompanies Memoir ME 7). **$3.00**

Map ME 1962-1 Geology, North Mountain, Inverness County, Nova Scotia, by G. C. Milligan and R. C. Parsons, 1962, black/white map, scale 1:31 680 (accompanies Memoir ME 7). **$1.00**

1:25 000

Map ME 1997-1 Geological Map of a Portion of the South-Central Cape Breton Highlands (part of NTS map sheet 11K/07), Victoria and Inverness Counties, Nova Scotia, by L. J. Ham, 1997, scale 1:25 000. Accompanies Paper ME 1997-1. **$6.00**

Map ME 1995-2, Second Edition Geological Map of a Portion of the South-Central Cape Breton Highlands (parts of NTS Map Sheets 11K/07 and 11K/10), Victoria and Inverness Counties, Nova Scotia, by R. J. Horne, revised September 1996, scale 1:25 000. **$6.00**

OFM ME 1994-6 Bedrock Geology Map of the Southeast Cape Breton Highlands, Nova Scotia (part of NTS Sheet 11K/07), Inverness and Victoria Counties, by L. J. Ham, 1994, scale 1:25 000. **$2.00**

OFM ME 1994-2 Location Map of Bedrock Samples, South-Central Cape Breton Highlands (NTS Sheets 11K/07 and 11K/10), Inverness and Victoria Counties, Nova Scotia, by R. J. Horne and L. J. Ham, 1994, scale 1:25 000 (2 sheets). **$4.00**

OFM ME 1994-1 Bedrock Geology Map of the South-Central Cape Breton Highlands, Nova Scotia (parts of NTS Sheets 11K/07 and 11K/10), Inverness and Victoria Counties, by R. J. Horne, 1994, scale 1:25 000. **$2.00**

OFM ME 1991-1 Preliminary Geological Map of West-Central Cape Breton Highlands (11K/07 and 11K/10), by R. J. Horne, 1991, scale 1:25 000. **$2.00**

Map ME 1986-2 Geological Map of the Windsor Area, Nova Scotia, by Reginald G. Moore and Stewart A. Ferguson, 1986, scale 1:25 000. **$5.00**

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1:20 000

OFM ME 1998-14 Geological Map of the McAdams Lake area, Cape Breton County (parts of NTS sheets 11F/15, 11F/16, 11K/01 and 11K/02), Nova Scotia, by C. E. White and S. M. Barr, 1998, 1 colour map, scale 1:20 000. **$5.00**

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Map ME 1995-1 Geological Map of the Springhill Coalfield, Cumberland County, Nova Scotia, by J. H. Calder, 1995, scale 1:10 000. **$6.00**

OFM ME 1994-5 Preliminary Geological Map, Rawdon Area, Hants County, Nova Scotia (NTS Sheet 11E/04), by R. J. Horne, 1994, scale 1:10 000. **$2.00**

OFM ME 1993-2 Geological Map of the Cogmagun River - Goshen Quadrangle (NTS 21H/01), Nova Scotia, by R. G. Moore, 1993, scale 1:10 000. **$2.00**

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OFM ME 1989-1 Geological Map of the Kentville-South Alton Quadrangle, compiled by Stewart A. Ferguson, 1989, scale 1:10 000. **$2.00**

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OFM ME 1989-2 Geological Map of the West Gore Quadrangle, by R. G. Moore, 1988, scale 1:10 000. **$2.00**

OFM ME 1988-43 Preliminary Geological Maps of the Cumberland Basin, Amherst (21H/16), by R. C. Boehner, R. J. Ryan and A. Deal, 11 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-42 Preliminary Geological Maps of the Cumberland Basin, Springhill and Apple River (21H/09 and 21H/10), by R. J. Ryan, A. Deal, J. H. Calder and R. C. Boehner, 24 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-41 Preliminary Geological Maps of the Cumberland Basin, Cape Chignecto and Parrsboro (21H/07 and 21H/08), by A. Deal, R. J. Ryan and R. C. Boehner, 13 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-40 Preliminary Geological Maps of the Cumberland Basin, Pugwash and Malagash (11E/13 and 11E/14), by R. J. Ryan, R. C. Boehner and A. Deal, 21 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-39 Preliminary Geological Maps of the Cumberland Basin, Tatamagouche and Oxford (11E/11 and 11E/12), by R. J. Ryan, R. C. Boehner and A. Deal, 23 maps, scale 1:10 000. **$2.00 each**

OFM ME 1988-24 Geological Map of New Minas - Canaan Quadrangle, compiled by Dr. Stewart A. Ferguson 1988, scale 1:10 000. **$2.00**

1:6000

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1:5000

OFM ME 1989-17 Geological Map of the Stellarton Basin (West Half), Pictou County, Nova Scotia, by W. D. Smith, K. S. Gillis, S. A. Montgomery, scale 1:5000. **$2.00**

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Map ME 1990-2 Geological Map of the Canadian Salt Company Limited Pugwash Mine (11E/13A), 730 Level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. **$5.00**

Map ME 1990-1 Geological Map of the Canadian Salt Company Limited Pugwash Mine (11E/13A), 630 Level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. **$5.00**

1:240

Map ME 1968-1 Silver Cliff Prospect, Dauphinee Brook, Inverness County, Nova Scotia, by G. C. Milligan and A. K. Chatterjee, 1968, black/white map, scale 1:240 (accompanies Memoir ME 7). **$1.00**

1:70

Map ME 1984-1 Geological Map of the Cochrane Hill Open-Pit Gold Deposit, Guysborough County, Nova Scotia, by P. K. Smith, scale 1:70. **$8.00**

GLACIAL/SURFICIAL GEOLOGY MAPS

Provincial Scale

1:1 000 000

OFM ME 1999-1 Index map to Nova Scotia Department of Natural Resources Bedrock Geology, Surficial Geology and Aeromagnetic Open File Maps of Nova Scotia [scale 1:1 000 000], compiled by K. D. Fraser, 1999, 1 map. **$5.00**

1:500 000

Map ME 1992-3 Surficial Geology Map of the Province of Nova Scotia, compiled by R. R. Stea, H. Conley and Y. Brown, 1992, scale 1:500 000. **$5.00**

Regional Scale

1:250 000

Map ME 1992-2 Glacial Geology Map of the South Mountain Batholith (NTS Sheets 11D, 21A and 20P), Western Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1992, scale 1:250 000. **$5.00**

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Map ME 1989-2 Map of the Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 2 (Central Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin ME 6). **$2.00 (white print copies only)**

Map ME 1989-1 Map of the Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 1 (Southwestern Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin ME 6). **$2.00 (white print copies only)**

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Map ME 1990-6 Surficial Geology Map of Parts of Halifax, Pictou, Antigonish and Guysborough Counties (Sheet 12), Map Sheets 11E/09, 10, 15, 16 and parts of 11E/07 and 11E/08, by R. R. Stea and R. A. Myers, 1990, scale 1:100 000. **$13.00**

OFM ME 1988-51 Till Geochemistry Map of Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, Map Sheet 13-88, scale 1:100 000. **$2.00**

OFM ME 1988-50 Till Geochemistry Map of Northern Mainland Nova Scotia, Clay Fraction Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, Map Sheet 13-88, scale 1:00 000. **$2.00**

OFM ME 1988-32 Till Geochemistry Map, Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. **$2.00**

OFM ME 1988-31 Till Geochemistry Map, Pictou and Antigonish Counties (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. **$2.00**

Map ME 1988-14 Surficial Geology Map of Parts of Colchester, Cumberland, Pictou and Hants Counties, Nova Scotia (Sheet 11), by R. R. Stea and P. W. Finck, 1988, scale 1:100 000. **$4.00**

Map ME 1988-13 Surficial Geology Map of Parts of Colchester, Cumberland, Pictou and Hants Counties, Nova Scotia (Sheet 10), by R. R. Stea and P. W. Finck, 1988, scale 1:100 000. **$4.00**

Map ME 1982-10 Pleistocene Geology and Till Geochemistry Map of Southwestern Nova Scotia (Sheets 7 and 8), by R. R. Stea and D. R. Grant, scale 1:100 000, (Sheet 9 is Map 1630A in Geological Survey of Canada Paper 85-17). **$8.00**

Map ME 1982-1 Pleistocene Geology and Till Geochemistry Map of South-Central Nova Scotia (Sheet 6), by R. R. Stea, scale 1:100 000, (Sheet 5 is in Open File Report ME 555). **$3.50**

Map ME 1981-1 Pleistocene Geology and Till Geochemistry Map, Central Nova Scotia, (Sheet 4; Sheets 1, 2 and 3 are in Paper ME 1979-4), by R. R. Stea and J. H. Fowler, scale 1:100 000. **$3.50**

Detailed Scale

1:50 000

OFM ME 1998-3 Surficial Geology of the Shubenacadie area (NTS 11E/03), Colchester, Halifax and Hants Counties, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, 1 coloured map, scale 1:50 000. **$5.00**

OFM ME 1998-2 Surficial Geology of the Bridgetown area (NTS 21A/14), Annapolis County, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, 1 coloured map, scale 1:50 000. **$5.00**

Map ME 1994-14 Glacial and Till Clast Geology Map of Gaspereau Lake, Nova Scotia (NTS Sheet 21A/15): South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. B. Bent, 1994, scale 1:50 000. **$6.00**

Map ME 1994-13 Glacial and Till Clast Geology Map of Milford, Nova Scotia (NTS 21A/11): South Mountain Batholith Project, by F. J. Boner, P. W. Finck and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-12 Glacial and Till Clast Geology Map of Kejimkujik Lake, Nova Scotia (NTS Sheets 21A/06 plus part of 21A/07): South Mountain Batholith Project, by P. W. Finck, F. J. Boner and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-11 Glacial and Till Clast Geology Map of Weymouth, Nova Scotia (NTS Sheet 21A/05): South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, 1994, scale 1:50 000. **$6.00**

Map ME 1994-10 Glacial and Till Clast Geology Map of Wentworth Lake, Nova Scotia (NTS Sheet 21A/04 plus part of 20P/13): South Mountain Batholith Project, by P. W. Finck, F. J. Boner and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-9 Glacial and Till Clast Geology Map of Lake Rossignol, Nova Scotia (NTS Sheet 21A/03 West): South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, 1994, scale 1:50 000. **$6.00**

OFM ME 1993-13 Glacial and Till Clast Geology Map of Digby (NTS 21A/12), Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1993, scale 1:50 000. **$2.00**

Map ME 1993-2 Glacial and Till Clast Geology Map of New Germany (NTS Sheet 21A/10), Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1992, scale 1:50 000. **$6.00**

OFM ME 1991-5 to OFM ME 1991-18 Aggregate Potential of Cumberland and Colchester Counties, 14 Preliminary Map Sheets, scale 1:50 000 (11E/02, 11E/03, 11E/05, 11E/06, 11E/07, 11E/11, 11E/12, 11E/13, 11E/14, 21H/07, 21H/08, 21H/09, 21H/10, 21H/16), by G. Prime, 1991. **$2.00 per NTS Map Sheet**

Map ME 1990-4 Till Clast and Glacial Geology Map of Chester (21A/09), Nova Scotia, by R. M. Graves and P. W. Finck, 1990, scale 1:50 000. **$11.00**

OFM ME 1988-52 Preliminary Till Geochemistry and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by F. J. Boner, P. W. Finck and R. M. Graves, scale 1:50 000. **$2.00**

OFM ME 1988-14 Glacial and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. G. Bent, scale 1:50 000. **$2.00**

Map ME 1987-4 Till Clast and Simplified Glacial Geology Map of Halifax-Sambro (11D/12 and 11D/05), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

Map ME 1987-3 Till Clast and Simplified Glacial Geology Map of Mount Uniacke (11D/13 West), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

Map ME 1987-2 Glacial Geology Map of Halifax and Sambro (11D/12 and 11D/05), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. **$6.00**

Map ME 1987-1 Glacial Geology Map of Mount Uniacke (11D/13 West), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. **$6.00**

1:25 000

OFM ME 1992-2 Surficial Geology of the South-Central Cape Breton Highlands (11K/07), by P. W. Finck, 1992, scale 1:25 000. **$2.00**

GEOCHEMISTRY MAPS

Provincial Scale

1:1 500 000

OFM ME 1990-15 Geochemical Atlas of Nova Scotia: Part I, Drainage Surveys, compiled by P. A. Lombard, 119 maps, 4 overlays. **$50.00**

Regional Scale

1:100 000

OFM ME 1988-51 Till Geochemistry Map of Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, Map Sheet 13-88, scale 1:100 000. **$2.00**

OFM ME 1988-50 Till Geochemistry Map of Northern Mainland Nova Scotia, Clay Fraction Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, Map Sheet 13-88, scale 1:00 000. **$2.00**

OFM ME 1988-32 Till Geochemistry Map, Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. **$2.00**

OFM ME 1988-31 Till Geochemistry Map, Pictou and Antigonish Counties (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. **$2.00**

Map ME 1988-14 Surficial Geology Map of Parts of Colchester, Cumberland, Pictou and Hants Counties, Nova Scotia (Sheet 11), by R. R. Stea and P. W. Finck, 1988, scale 1:100 000. **$4.00**

Map ME 1988-13 Surficial Geology Map of Parts of Colchester, Cumberland, Pictou and Hants Counties, Nova Scotia (Sheet 10), by R. R. Stea and P. W. Finck, 1988, scale 1:100 000. **$4.00**

Map ME 1982-10 Pleistocene Geology and Till Geochemistry Map of Southwestern Nova Scotia (Sheets 7 and 8), by R. R. Stea and D. R. Grant, scale 1:100 000, (Sheet 9 is Map 1630A in Geological Survey of Canada Paper 85-17). **$8.00**

Map ME 1982-1 Pleistocene Geology and Till Geochemistry Map of South-Central Nova Scotia (Sheet 6), by R. R. Stea, scale 1:100 000, (Sheet 5 is in Open File Report ME 555). **$3.50**

Map ME 1981-1 Pleistocene Geology and Till Geochemistry Map, Central Nova Scotia, (Sheet 4; Sheets 1, 2 and 3 are in Paper ME 1979-4), by R. R. Stea and J. H. Fowler, scale 1:100 000. **$3.50**

Detailed Scale

1:50 000

OFM ME 1998-3 Surficial Geology of the Shubenacadie area (NTS 11E/03), Colchester, Halifax and Hants Counties, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, 1 coloured map, scale 1:50 000. **$5.00**

OFM ME 1998-2 Surficial Geology of the Bridgetown area (NTS 21A/14), Annapolis County, Nova Scotia, by R. R. Stea and C. M. Kennedy, 1998, 1 coloured map, scale 1:50 000. **$5.00**

Map ME 1994-14 Glacial and Till Clast Geology Map of Gaspereau Lake, Nova Scotia (NTS Sheet 21A/15): South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. B. Bent, 1994, scale 1:50 000. **$6.00**

Map ME 1994-13 Glacial and Till Clast Geology Map of Milford, Nova Scotia (NTS 21A/11): South Mountain Batholith Project, by F. J. Boner, P. W. Finck and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-12 Glacial and Till Clast Geology Map of Kejimkujik Lake, Nova Scotia (NTS Sheets 21A/06 plus part of 21A/07): South Mountain Batholith Project, by P. W. Finck, F. J. Boner and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-11 Glacial and Till Clast Geology Map of Weymouth, Nova Scotia (NTS Sheet 21A/05): South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, 1994, scale 1:50 000. **$6.00**

Map ME 1994-10 Glacial and Till Clast Geology Map of Wentworth Lake, Nova Scotia (NTS Sheet 21A/04 plus part of 20P/13): South Mountain Batholith Project, by P. W. Finck, F. J. Boner and R. M. Graves, 1994, scale 1:50 000. **$6.00**

Map ME 1994-9 Glacial and Till Clast Geology Map of Lake Rossignol, Nova Scotia (NTS Sheet 21A/03 West): South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, 1994, scale 1:50 000. **$6.00**

OFM ME 1993-13 Glacial and Till Clast Geology Map of Digby (NTS 21A/12), Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1993, scale 1:50 000. **$2.00**

Map ME 1993-2 Glacial and Till Clast Geology Map of New Germany (NTS Sheet 21A/10), Nova Scotia, by P. W. Finck, R. M. Graves and F. J. Boner, 1992, scale 1:50 000. **$6.00**

OFM ME 1991-5 to OFM ME 1991-18 Aggregate Potential of Cumberland and Colchester Counties, 14 Preliminary Map Sheets, scale 1:50 000 (11E/02, 11E/03, 11E/05, 11E/06, 11E/07, 11E/11, 11E/12, 11E/13, 11E/14, 21H/07, 21H/08, 21H/09, 21H/10, 21H/16), by G. Prime, 1991. **$2.00 per NTS Map Sheet**

Map ME 1990-4 Till Clast and Glacial Geology Map of Chester (21A/09), Nova Scotia, by R. M. Graves and P. W. Finck, 1990, scale 1:50 000. **$11.00**

OFM ME 1988-52 Preliminary Till Geochemistry and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by F. J. Boner, P. W. Finck and R. M. Graves, scale 1:50 000. **$2.00**

OFM ME 1988-14 Glacial and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. G. Bent, scale 1:50 000. **$2.00**

Map ME 1987-4 Till Clast and Simplified Glacial Geology Map of Halifax-Sambro (11D/12 and 11D/05), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

Map ME 1987-3 Till Clast and Simplified Glacial Geology Map of Mount Uniacke (11D/13 West), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. **$6.00**

Map ME 1987-2 Glacial Geology Map of Halifax and Sambro (11D/12 and 11D/05), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. **$6.00**

Map ME 1987-1 Glacial Geology Map of Mount Uniacke (11D/13 West), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. **$6.00**

1:25 000

OFM ME 1992-2 Surficial Geology of the South-Central Cape Breton Highlands (11K/07), by P. W. Finck, 1992, scale 1:25 000. **$2.00**

GEOPHYSICS MAPS

Provincial Scale

1:2 000 000

Map ME 1979-5 to Map ME 1979-9 Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. **$1.00 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

1:1 000 000

OFM ME 1999-1 Index map to Nova Scotia Department of Natural Resources Bedrock Geology, Surficial Geology and Aeromagnetic Open File Maps of Nova Scotia [scale 1:1 000 000], compiled by K. D. Fraser, 1999, 1 map. **$5.00**

1:500 000

Map ME 1979-3 Geological Map of Nova Scotia, Bouguer Gravity Anomaly Edition, by J. D. Keppie, scale 1:500 000, 1979, with Metamorphic and Structural Map Inserts by J. D. Keppie and G. K. Muecke, scale 1:1 000 000. **$2.50 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

Regional Scale

1:125 000

Map ME 2000-2 Enhanced Aeromagnetic and Digital Elevation Map of Eastern Nova Scotia, compiled by M. S. King, 2000, scale 1:250 000. **$6.00**

Map ME 1983-2 Calculated Vertical Magnetic Gradient Map of the Cape Breton Highlands, Inverness and Victoria Counties, Nova Scotia, scale 1:125 000. **$5.00**

Detailed Scale

1:50 000

OFM ME 1997-33 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 20P/15, Port Mouton, Queens and Shelburne Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-32 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 20P/14, Shelburne, Shelburne and Queens Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-31 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 20P/13, Tusket, Yarmouth and Shelburne Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-30 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 20O/16, Yarmouth, Yarmouth County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-28 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/09, Chester, Lunenburg and Halifax Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-27 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/08, Lunenburg, Lunenburg County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-26 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/07, Bridgewater, Lunenburg and Queens Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-25 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/04, Wentworth Lake, Yarmouth and Digby Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-24 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/03, Lake Rossignol, Shelburne, Yarmouth, Queens and Digby Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-23 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/02, Liverpool, Queens and Lunenburg Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-22 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 21A/01, LaHave Islands, Lunenburg County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-21 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/12, Halifax, Halifax County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-20 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11F/05, Guysborough, Guysborough and Antigonish Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-19 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11F/04, Country Harbour, Guysborough County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-18 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11F/03 and 11F/06, Larrys River and Chedabucto Bay, Guysborough County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-17 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11E/08, Lochaber, Pictou, Guysborough, and Antigonish Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-16 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11E/04, Kennetcook, Hants County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-15 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11E/03, Shubenacadie, Halifax, Colchester and Hants Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-14 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11E/02, Upper Musquodoboit, Halifax, Guysborough and Colchester Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-13 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11E/01, Liscomb, Guysborough and Halifax Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-12 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/16, Ecum Secum, Halifax and Guysborough Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-11 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/15, Tangier, Halifax County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-10 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/14, Musquodoboit Harbour, Halifax County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-9 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/13, Mount Uniacke, Halifax and Hants Counties, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-8 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/11, West Chezzetcook, Halifax County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

OFM ME 1997-7 Meguma Terrane Enhanced (Second Vertical Derivative) Aeromagnetic Digital Data, NTS Map Sheet 11D/10, Owls Head, Halifax County, Nova Scotia, by M. S. King, 1997, scale 1:50 000. **$5.00**

MINERAL DEPOSITS MAPS

Provincial Scale

1:2 000 000

Map ME 1979-5 to Map ME 1979-9 Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. **$1.00 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

1:1 000 000

OFM ME 1998-15 Map of Active Mines in Nova Scotia, by Ian McLellan, June 1998, 1 map, scale 1:1 000 000. **$5.00**

1:500 000

OFM ME 1997-35 Historic Underground Mining + Advanced Exploration Sites: Abandoned Mine Openings, compiled by Mining Engineering Section, Nova Scotia Department of Natural Resources, September 24, 1997. **$5.00**

Map ME 1991-1 Map of Gypsum and Anhydrite Resources in Nova Scotia, compiled by G. C. Adams, 1991, scale 1:500 000 (accompanies EGS ME 1991-1). **$5.00**

Map ME 1985-1 Industrial Mineral Commodities Map of the Province of Nova Scotia, compiled by John H. Fowler, 1985, scale 1:500 000. **$5.00**

Map ME 1983-5 Metallogenic Map of Nova Scotia, by A. K. Chatterjee, scale 1:500 000, 1983. **$5.00**

Map ME 1983-3 Salt and Potash Resources Map of Nova Scotia, by R. C. Boehner, scale 1:500 000 (accompanies Bulletin ME 5). **$2.00 (white print copies only)**

Map ME 1979-2 Geological Map of Nova Scotia, Metallic Mineral Occurrence Edition, by J. D. Keppie, D. J. Gregory, A. K. Chatterjee and N. A. Lyttle, scale 1:500 000, 1979, with Structural and Metamorphic Map Inserts by J. D. Keppie and G. K. Muecke, scale 1:1 000 000. **$2.50 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

Regional Scale

1:250 000

Map ME 1989-3 Map of the Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 3 (Cape Breton Island), 1986, scale 1:250 000 (accompanies Bulletin ME 6). **$2.00 (white print copies only)**

Map ME 1989-2 Map of the Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 2 (Central Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin ME 6). **$2.00 (white print copies only)**

Map ME 1989-1 Map of the Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 1 (Southwestern Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin ME 6). **$2.00 (white print copies only)**

1:125 000

Map ME 1985-6 Aggregate Resources Map, Cape Breton Island, by W. J. Wright, scale 1:125 000 (locates and shows the type, quality and observed thickness of sand and gravel deposits). **$3.00**

Map ME 1985-3, Map ME 1985-4, Map ME 1985-5 Aggregate Resources Map, Cape Breton Island, by W. J. Wright, scale 1:125 000, (locates and names aggregate pits and quarries). **$3.00 each, $10.00 set**

1:100 000

OFM ME 1986-49 to OFM ME 1986-56 Gold Compilation of the Meguma Terrane in Nova Scotia, by J. McMullin, G. Richardson, T. Goodwin, 8 maps, scale 1:100 000. **$2.00 each**

Detailed Scale

1:50 000

OFM ME 1991-5 to OFM ME 1991-18 Aggregate Potential of Cumberland and Colchester Counties, 14 Preliminary Map Sheets, scale 1:50 000 (11E/02, 11E/03, 11E/05, 11E/06, 11E/07, 11E/11, 11E/12, 11E/13, 11E/14, 21H/07, 21H/08, 21H/09, 21H/10, 21H/16), by G. Prime, 1991. **$2.00 per NTS Map Sheet**

1:6000

OFM ME 1990-2 Map of the Glencoe Limestone Deposit, Inverness County (11F/14), 1988 Diamond-Drilling; Diamond-Drill Holes and Sections, by R. H. MacDonald, scale 1:6000. **$2.00**

1:1600

Map ME 1990-3 Geological Map of the Canadian Salt Company Limited Pugwash Mine (11E/13A), 830 Level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. **$5.00**

Map ME 1990-2 Geological Map of the Canadian Salt Company Limited Pugwash Mine (11E/13A), 730 Level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. **$5.00**

Map ME 1990-1 Geological Map of the Canadian Salt Company Limited Pugwash Mine (11E/13A), 630 Level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. **$5.00**

1:70

Map ME 1984-1 Geological Map of the Cochrane Hill Open-Pit Gold Deposit, Guysborough County, Nova Scotia, by P. K. Smith, scale 1:70. **$8.00**

STRUCTURE/TECTONIC MAPS

Provincial Scale

1:2 000 000

Map ME 1979-5 to Map ME 1979-9 Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. **$1.00 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

1:500 000

Map ME 1982-11 Tectonic Map of Nova Scotia, by J. D. Keppie, scale 1:500 000, 1982. **$5.00**

LAND USE MAPS

Provincial Scale

1:500 000

OFM ME 2000-1 Land Designation and Ownership in Nova Scotia, researched and compiled by David Hopper, Fred J. Bonner and Brian E. Fisher, 2000, scale 1:500 000. **$5.00**

OFM ME 1997-35 Historic Underground Mining + Advanced Exploration Sites: Abandoned Mine Openings, compiled by Mining Engineering Section, Nova Scotia Department of Natural Resources, September 24, 1997. **$5.00**

Detailed Scale

1:50 000

OFM ME 1989-5 to OFM ME 1989-9 Mineral Resource Land Use Maps for Lunenburg County, by D. B. Hopper and H. J. Gillis, 1989, 5 maps, scale 1:50 000. **$2.00 per map, $10.00 set**

OFM ME 1988-44 to OFM ME 1988-49 Mineral Resource Land Use Maps for Kings County (21A/10, 21A/15, 21A/16, 21H/01, 21H/01, 21H/02, 21H/08), by D. B. Hopper and H. J. Gillis, 1989, 6 maps, scale 1:50 000. **$2.00 per map; $12.00 set**

OFM ME 1988-33 to OFM ME 1988-38 Mineral Resource Land Use Maps for Cape Breton County, by D. B. Hopper and H. J. Gillis, 1988, 6 maps, scale 1:50 000. **$2.00 per map; $12.00 set**

OFM ME 1988-17 to OFM ME 1988-22 Mineral Resource Land Use Maps for Hants County, by D. B. Hopper and H. J. Gillis, 1988, 6 maps, scale 1:50 000. **$2.00 per map; $12.00 set**

OFM ME 1988-1 to OFM ME 1988-12 Mineral Resource Land Use Maps for Halifax County, by D. B.

Hopper and C. A. Dobson, 1988, 12 maps, scale 1:50 000. **$2.00 per map; $24.00 set**

GENERAL MAPS

Provincial Scale

1:2 000 000

Map ME 1979-5 to Map ME 1979-9 Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. **$1.00 (Please note that Geological Map ME 2000-1 is the most recent provincial scale geology map of Nova Scotia)**

1:1 000 000

OFM ME 1999-1 Index map to Nova Scotia Department of Natural Resources Bedrock Geology, Surficial Geology and Aeromagnetic Open File Maps of Nova Scotia [scale 1:1 000 000], compiled by K. D. Fraser, 1999, 1 map. **$5.00**

OFM ME 1998-16 Index Map to Geological Survey of Canada Open File Geological Maps of Nova Scotia, 1969-1998, by K. D. Fraser, T. L. Lenfesty, 1998, scale 1:1 000 000. **$2.00**

OFM ME 1998-15 Map of Active Mines of Nova Scotia, by Ian McLellan, June, 1998, 1 map, scale 1:1 000 000. **$5.00**

1:640 000

Outside Publication ME 1989-1 Geological Highway Map of Nova Scotia, Second Edition, by Howard V. Donohoe, Jr., and R. G. Grantham, scale 1:640 000, 1989 (Atlantic Geoscience Society, Special Publication Number 1). **$3.50**

1:500 000

Claim Reference Map (compilation) of Nova Scotia, updated quarterly, scale 1:500 000. **$5.00**

OFM ME 1997-35 Historic Underground Mining + Advanced Exploration Sites: Abandoned Mine Openings, compiled by Mining Engineering Section, Nova Scotia Department of Natural Resources, September 24, 1997. **$5.00**

Detailed Scale

1:31 680

Claim Reference Maps of Nova Scotia, undated, scale 1:31 680. **$1.00 per 1:50 000 NTS Map Sheet Quarter Section**

ACTS

Provincial legislation.

Mineral Resources Act and Regulations, S.N.S. 1990, c. 18. **$9.35**

Gypsum Mining Income Tax Act, R.S.N.S. 1979, c. 190. **$1.00**

Treasure Trove Act, 1954. **FREE**

ANNUAL REPORTS

Summary reports of the Department's activities and programs.

1993/94

Annual Report for the Fiscal Year Ending March 31, 1994, by Nova Scotia Department of Natural Resources, 1995, 89 pages. **FREE**

1992/93

Annual Report for the Fiscal Year Ending March 31, 1993, by Nova Scotia Department of Natural Resources, 1994, 83 pages. **FREE**

1991/92

Annual Report for the Fiscal Year Ending March 31, 1992, by Nova Scotia Department of Natural Resources, 1994, 77 pages. **FREE**

1990/91

Annual Report for the Fiscal Year Ending March 31, 1991, by Nova Scotia Department of Mines and Energy, 1992, 117 pages. **FREE**

BULLETINS

Detailed scientific reports on various geoscience topics on a regional or provincial basis.

Bulletin ME 7 Structure of the Canadian Appalachians, by J. D. Keppie, 1992, 89 pages, 3 maps, 3 figures in back pocket. **$8.00 (Microfiche $2.00)**

Bulletin ME 6 Evaluation of Nova Scotia's Peatland Resources, by A. R. Anderson and W. A. Broughm, 1988, 109 pages, 3 maps, scale 1:250 000. **$15.00**

Bulletin ME 5 Salt and Potash Resources in Nova Scotia, by R. C. Boehner, 1986, 346 pages, 8½" x 11" format, includes Map ME 1983-3, scale 1:500 000. **$17.00 (Microfiche $5.00)**

Bulletin ME 4 Barite, Celestite and Fluorite in Nova Scotia, by G. W. Felderhof, 1978, 463 pages, 200 figures, 12 tables. **$13.00**

Bulletin ME 3 Assessment of Peat Moss Occurrences in Guysborough, Antigonish, Pictou, Colchester and Cumberland Counties, Nova Scotia, by D. R. Sutherland and F. S. Shea, 1976, 301 pages. **$7.00**

Bulletin ME 2 (Part 1) Limestones and Dolomites of Nova Scotia, Part I - Cape Breton Island, by F. S. Shea and D. A. Murray, 1969, 300 pages, 1 map. **$4.00**

Bulletin ME 2 (Part 2) Limestones and Dolomites of Nova Scotia, Part II - Antigonish, Guysborough, Pictou, and Cumberland Counties, by D. A. Murray, 1975, 155 pages. **$6.50**

Note: For Part 3, Colchester and Halifax Counties, see Open File Report ME 2000-3.

Bulletin ME 1 Port Hawkesbury Project - Geology, Geochemistry and Groundwater Investigations of Southwest Inverness and Richmond Counties, Nova Scotia, by F. S. Shea and J. D. Wallace, 1962, 73 pages, 5 maps. **$2.00**

CONTRIBUTION SERIES

Detailed scientific papers on specific geoscience topics authored by Minerals and Energy Branch staff and published externally in scientific journals and monographs.

CS ME 1999-5 Carboniferous Barite-Fluorite Mineralization in the Late Devonian Kinsac Pluton, Southern Nova Scotia, by D. J. Kontak, R. J. Horne, K. Ansdell, D. A. Archibald, 1999; *in* Atlantic Geology, vol. 35 (1999), pages 109-127. **FREE**

CS ME 1999-4 New Constraints on the Age and Origin of the Dunbrack Pb-Cu-Zn-Ag Deposit, Musquodoboit Batholith, Southern Nova Scotia, by D. J. Kontak, K. Ansdell, D. A. Archibald, 1999; *in* Atlantic Geology, vol. 35 (1999), pages 19-42, 3 maps. **FREE**

CS ME 1999-3 Using Whole Rock Geochemistry to Locate the Source of Igneous Erratics from Drumlins on the Atlantic Coast of Nova Scotia, by Rudolph R. Stea, Nova Scotia Department of Natural Resources, Georgia Pe-Piper, Saint Mary's University, 1999; *in* Boreas, vol. 28, pages 308-325, 7 maps. **FREE**

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Memoir ME 9 Geology of the Loch Lomond Basin and Glengarry Half Graben, Richmond and Cape Breton Counties, Cape Breton Island, Nova Scotia, by R. C. Boehner and G. Prime, 1993, 68 pages, 1 map. (Includes Map ME 1985-2, Geology of the Loch

Lomond Basin and Glengarry Half Graben, Nova Scotia, scale 1:50 000). **$8.00 (Microfiche $2.00)**

Memoir ME 8 Geology of the Antigonish Basin, Antigonish County, Nova Scotia, by R. C. Boehner and P. S. Giles, 1993, 132 pages. **$10.00 (Microfiche $3.00)**

Memoir ME 7 The Geology of the George River Series, Cape Breton, Stratigraphy, Structure and Economic Geology, by G. C. Milligan, 1970, 111 photocopied pages, 5 coloured and 2 black/white maps in back pocket: Map ME 1962-1, Map ME 1963-1, Map ME 1963-2, Map ME 1967-1, Map ME 1967-2 and Map ME 1967-3. **$10.00. (Microfiche $3.00)**

Memoir ME 5 Pleistocene Geology of the Annapolis Valley, Nova Scotia, by C. F. Hickox, 1962, 36 pages, 1 map. **$2.00**

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Memoir ME 1 Gypsum and Anhydrite in Nova Scotia, by N. R. Goodman, 1952, 75 pages. **Out of Print (Microfiche only $2.00)**

MISCELLANEOUS PUBLICATIONS

Older reports on various geoscience topics that were originally published without a series title.

MP ME 1975-4 Bibliography of the Geology of Nova Scotia, by D. J. Gregory, 1975, 237 pages. **Out of Print (Microfiche only $4.00)**

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MP ME 1975-2 Drilling Logs of Government Core Drills, 1973, by I. MacDougall and D. W. Grimm, 76 pages. **$1.00**

MP ME 1975-1 Drilling Logs of Government Core Drills, 1972, by I. MacDougall and D. W. Grimm, 85 pages. **$1.00**

NOTE: Drilling logs after 1973 are published as part of the Report Series; e.g. Drilling Logs for 1974 are in Report ME 1976-1.

MP ME 1972-4 Geology of the Middle River and Baddeck Forks Map Areas, Victoria County, Nova Scotia, by B. E. Jones and T. G. N. Covert, 1972, 124 pages, 5 maps. **$5.00**

MP ME 1972-3 Clay and Sand Deposit at Elmsvale, Halifax County, Nova Scotia, by J. H. Fowler, 1972, 62 pages, drillhole sections. **Out of Print (Microfiche Only $2.00)**

MP ME 1972-1 Drilling Logs of Government Core Drills, 1971, by C. F. Townsend and D. W. Grimm, 81 pages. **$1.00**

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MP ME 1969-1 Drilling Logs of Government Core Drills, 1968 by C. F. Townsend and D. W. Grimm, 58 pages. **$1.00**

MP ME 1968-2 Core Drilling in Nova Scotia with Government Drills, 1871-1966, 176 pages. **$2.00**

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MP ME 1966-1 Drilling Logs of Government Core Drills, 1965, by C. F. Townsend and D. W. Grimm, 55 pages. **$1.00**

MP ME 1965-1 Drilling Logs of Government Core Drills, 1964, by C. F. Townsend and D. W. Grimm, 43 pages. **$1.00**

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MP ME 1958-2 Possibilities for Occurrence of Petroleum Reservoirs in Nova Scotia, by W. A. Bell, 1958, 177 pages. **$1.00**

NOTE: Drilling Logs prior to 1958 are in Nova Scotia Department of Mines Annual Reports.

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OFR ME 2000-1 NTS Location, Author and Citation Index to Nova Scotia Department of Natural Resources, Minerals and Energy Branch Assessment Reports, 1996-1999, compiled by Paul D. McCulloch, Sandra Marshall, Norman A. Lyttle and J. Susan Saunders, 2000, 116 pages. **$10.00**

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OFR ME 1988-63 An Assessment of the Hydrocarbon and Compressed Air Storage Potential of Nova Scotia: A Summary, by Nolan, Davis and Associates Ltd., 1988, 22 pages. **$3.00**

OFR ME 1988-59 Interpretation of Till Geochemical Data in Nova Scotia, Canada, Using Mapped Till Units, Multi-Element Anomaly Patterns, and the Relationship of Till Clast Geology to Matrix Geochemistry, by R. G. Turner and R. R. Stea, 1988, 39 pages. **$5.00**

OFR ME 1988-57 Gypsum - Anhydrite Potential, Meadows Road Area, Cape Breton County, by G. Adams, 1988, 29 pages. **$5.00**

OFR ME 1988-56 An Assessment of the Hydrocarbon and Compressed Air Storage Potential of Nova Scotia Salt Deposits, by Nolan, Davis and Associates Ltd., 1988, 195 pages. **$20.00**

OFR ME 1988-55 Multi-Element Ratings Maps for Meguma Zone Lake Sediments, by P. J. Rogers, 1989, 34 pages, 3 maps. **$5.00**

OFR ME 1988-40 Aggregate Market Study for New Brunswick and Nova Scotia, by ADI Limited, 1988, Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 309 pages. **$17.00**

OFR ME 1988-39 Marine Transport Study for Nova Scotia, by Leslie MacIntyre Maritime Associates Inc., May 1988, Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 38 pages. **$5.00**

OFR ME 1988-13 A Study of U. S. East Coast Industrial Mineral Markets for New Brunswick, Newfoundland and Nova Scotia, by Metals Economics Group, 1988, Prepared for Mineral Policy Sector, Energy Mines and Resources Canada, 286 pages. **$15.00**

OFR ME 1988-11 Geochemical Investigations in the Rushmere - Moosefly Lakes Area, Yarmouth County, Nova Scotia (NTS 21A/04A), by R. F. Mills, 1988, 23 pages. **$3.00**

OFR ME 1987-32 Sulphur in Nova Scotia: Pugwash and Hilden Occurrences, by D. C. Carter, R. C. Boehner and G. C. Adams, 1987, 7 pages. **$5.00**

OFR ME 1987-27 Potential Crushed Stone Deposits on Tidewater in Nova Scotia, by G. B. Dickie, 1987, 15 pages. **$5.00**

OFR ME 1987-23 Report on the English Property (McKeen Quarry), Pictou County, by G. B. Dickie, 1987, 12 pages. **$5.00**

OFR ME 1987-5 Report on the Potential Stone Quarry, MacKenzie Farm, Hardwood Hill, Pictou County, Nova Scotia, by G. Dickie, 1986, 37 pages. **$5.00**

OFR ME 1987-2 Market Analysis for New Brunswick, Nova Scotia and Newfoundland Dimension Stone, by the DPA Group Incorporated in association with Jacques Whitford and Associates Limited, March 1987, 66 pages. **$10.00**

OFR ME 1986-54 The U.K. Experience on the Effects of Offshore Sand and Gravel Extraction on Coastal Erosion and the Fishing Industry, by R. Warren Drinnan and Douglas G. Bliss, Dobrocky Sea Tech Limited, August 1986, 90 pages. **$10.00**

OFR ME 1986-39 Agricultural Gypsum Project, by Peter Luke, 1986, 9 pages. **$3.00**

OFR ME 1986-25 The Gypsum Industry in Nova Scotia - Present Status and Future Prospects, by R. E. Wright and J. H. Brown; prepared for Nova Scotia Department of Mines and Energy by Centre for Resource Studies, Queen's University, 1985, 125 pages. **$15.00**

OFR ME 1986-21 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), 235 pages. **$10.00**

OFR ME 1986-20 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11K, 11N), 355 pages. **$10.00**

OFR ME 1986-19 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Central Nova Scotia (Map Sheets 11D, 11E), 280 pages. **$10.00**

OFR ME 1986-13 Study of Markets for Silica and Silica Sands Accessible from Nova Scotia and New Brunswick, by ADI Limited, 244 pages. **$10.00**

OFR ME 1986-12 A Study of Industrial Minerals Used in Oil and Gas Exploration on the Eastern Canadian Offshore, by Jacques, Whitford and Associates, and Cleland, Dunsmuir Consulting Limited, 231 pages. **$17.00**

OFR ME 1986-10 Study of Markets for Aggregate Materials Accessible from Nova Scotia and New Brunswick, by ADI Limited, March 1986, 398 pages. **$10.00**

NOTE: As of January 1986, all new Open File Reports have a report number assigned based upon the year of publication.

OFR ME 656 The Development Potential for Nova Scotia's Offshore Aggregate and Placer Resources, by John Fowler and Craig Miller, 1985, 69 pages. **$10.00**

OFR ME 651 Gypsum Property, Ownership and Leases, by Mark W. G. King, 1985, 140 pages. **$10.00**

OFR ME 650 Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia, edited by A. K. Chatterjee and D. B. Clarke, 1985, 264 pages. **$15.00**

OFR ME 648 Current Market Economics of the Strontium Minerals by Metals Economic Group of Halifax, Nova Scotia, and Boulder, Colorado, 1985, 54 pages. **$5.00**

OFR ME 621 Effects of Location on Mine Development Potential: Nova Scotia's Competitive Position in Canada, by D. W. Davis, B. W. MacKenzie and M. L. Bilodeau, 1985, 103 pages. **$15.00**

OFR ME 608 Industrial Mineral Occurrences Map and Data Compilation, Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), by M. Ponsford, G. DeMont and N. A. Lyttle, 1985, 21 pages, 1 map. **$4.00**

OFR ME 607 Industrial Mineral Occurrences Map and Data Compilation, Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11N), by M. Ponsford, G. DeMont and N. A. Lyttle, 1985, 29 pages, 1 map. **$4.00**

OFR ME 606 Industrial Mineral Occurrences Map and Data Compilation, Central Nova Scotia (Map Sheets 11D, 11E), by M. Ponsford, G. DeMont and N. A. Lyttle, 1985, 22 pages, 1 map. **$4.00**

OFR ME 605 Regional Lake Sediment Survey of the Meguma Zone, Southern Nova Scotia: New Analytical Data, by P. J. Rogers, M. A. MacDonald and D. W. Rigby, 1985, 65 pages, 2 maps. **$5.00**

OFR ME 603 Preliminary Feasibility Study for an Underground Gold Mining Operation in Central Nova Scotia, by Nova Scotia Department of Mines and Energy, 1984, 62 pages, 2 maps. **$5.00**

OFR ME 601 Metallic Mineral Occurrences Map and Data Compilation, Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), by M. Ponsford and N. A. Lyttle, 1984, 21 pages, 2 maps. **$3.00**

OFR ME 600 Metallic Mineral Occurrences Map and Data Compilation, Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11K, 11N), by M. Ponsford and N. A. Lyttle, 1984, 23 pages, 2 maps. **$3.00**

OFR ME 599 Metallic Mineral Occurrences Map and Data Compilation, Central Nova Scotia (Map Sheets 11D and 11E), by M. Ponsford and N. A. Lyttle, 1984, 21 pages, 2 maps. **$3.00**

OFR ME 329 The Glencoe Limestone and Dolomite Survey, by D. J. MacNeil, 1977, 252 pages, 12 maps. **$15.00**

OFR ME 50 Carboniferous Stratigraphy and Economic Geology, Halifax, Hants and Colchester Counties, Nova Scotia; Canadian Institute of Mining and Metallurgy, Geology Division, Field Guide, by Mining Society of Nova Scotia, Atlantic Geoscience Society and Nova Scotia Department of Mines, 1974, 48 pages. **$1.00**

OUTSIDE PUBLICATIONS

Various externally published reports and maps on geoscience topics authored by non-Minerals and Energy Branch staff.

OP ME 1998-2

A Special Issue Devoted to Lead-Zinc Mineralization and Basinal Brine Movement, Lower Windsor Group

(Viséan), Nova Scotia, Canada; *in* Economic Geology and the Bulletin of the Society of Economic Geologists, v. 93, September-October 1998, no. 6, 260 pages. **$21.00**

OP ME 1998-1 Discovering Rocks, Minerals and Fossils in Atlantic Canada, A Geological Field Guide to Selected Sites in Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick, edited by P. Wallace, 1998, 186 pages; Atlantic Geoscience Society, Special Publication No. 14. **$25.00**

OP ME 1995-1 Proceedings: 30th Forum on the Geology of Industrial Minerals (1994), edited by S. A. A. Merlini, 1995; New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Miscellaneous Report 16, 261 pages. **$14.75**

OP ME 1991-1 A Guide to the Geology, Landscapes and Mineral Resources of Nova Scotia, by Craig K. Miller and G. C. Milligan, 1991; Atlantic Geoscience Society, Special Publication No. 6 (Preliminary Edition), 188 pages. **$5.00**

OP ME 1988-1 Atlantic Geoscience Society, Colloquium '88, Antigonish, N. S. (Abstracts of Papers). **$4.00**

OP ME 1987-2 The Mining Society of Nova Scotia 1887-1987, by D. Pigot, published by the Mining Society of Nova Scotia, June 1987, 125 pages. **$10.00**

OP ME 1987-1 Quaternary Glaciations, Geomorphology and Sea Level Changes: Bay of Fundy Region, by R. R. Stea, Field Trip, July 19-30, 1987, for NATO Advanced Study Institutes Programme, International Advanced Course on Late Quaternary Sea Level Correlations and Applications, Halifax, Nova Scotia; 79 pages. **$10.00**

OP ME 1986-5 Trip No. 14 Lithostratigraphic, Physical Diagenetic and Economic Aspects of the Pennsylvanian-Permian Transition Sequence of Prince Edward Island and Nova Scotia; H. W. van de Poll, J. R. DeGrace, R. J. Ryan, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985). **$7.00**

OP ME 1986-4 Trip No. 11 Turbidite-Hosted Gold Deposits, Meguma Domain, Eastern Nova Scotia; P. K. Smith, S. J. Haynes, B. E. Jones, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985), 67 pages. **$7.00**

OP ME 1986-3 Trip No. 10 Igneous and Metamorphic Geology of the Cape Breton Highlands; S. M. Barr, R. A. Jamieson, R. D. Raeside, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985), 48 pages. **$5.00**

OP ME 1986-2 Behind the Headlines: Moose River to Shangri-La, by Ralph Kelly Morton, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985), 197 pages. **$14.95**

OP ME 1986-1 Trip No. 1 Appalachian Geotraverse (Canadian Mainland); J. D. Keppie, K. Currie, J. B. Murphy, *et al.*, 1986; *in* Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985), 181 pages. **$15.00**

OP ME 1981-1 Malagash Salt, compiled and edited by John R. MacQuarrie, c. 1975, 1981, 109 pages. **$5.00**

PAPERS

Detailed scientific papers on specific geoscience topics and/or specific areas.

Paper ME 1997-1 The Geology of a Portion of the South-Central Cape Breton Highlands (part of NTS map sheet 11K/07), Victoria and Inverness Counties, Nova Scotia, by L. J. Ham, 1997, 43 pages, 1 coloured map, includes Map ME 1997-1, scale 1:25 000 in back pocket. **$15.00**

Paper ME 1995-2 Geology of the South-Central Cape Breton Highlands (Parts of NTS Sheets 11K/07 and 11K/10), Inverness and Victoria Counties, Nova Scotia, by R. J. Horne, 61 pages, includes Map ME 1995-2 in back pocket. **$20.00**

Paper ME 1995-1 The Compositional Development of Tills Overlying the South Mountain Batholith, Nova Scotia, by P. W. Finck and R. R. Stea, 1995, 52 pages, includes Map ME 1992-2. **$15.00**

Paper ME 1994-1 A Diamond-Drilling Program near the Amherst Market, Investigating Bedrock Aggregate Potential in the Northwestern Cobequid Highlands, Nova Scotia, by G. Prime, 1994, 38 pages. **$4.00**

Paper ME 1993-2 Quaternary Stratigraphy and Placer Gold Potential of the Inner Scotian Shelf, by R. R. Stea, S. Pecore and G. B. J. Fader, 1993, 62 pages. **$7.00 (Microfiche $2.00)**

Paper ME 1993-1 An Evaluation of Debris Avalanches in the Central Cape Breton Highlands, Nova Scotia, by P. W. Finck, 1993, 65 pages. **$9.00 (Microfiche $2.00)**

Paper ME 1992-1 Surficial and Environmental Geology of the Western Cape Breton Highlands, Nova Scotia, by P. W. Finck, 1992, 22 pages, map and 18 plates in back pocket. **$10.00 (Microfiche $2.00)**

Paper ME 1989-3 Re-evaluation of the Coal Resources of Western Cape Breton Island, by P. A. Hacquebard, K. S. Gillis and D. S. Bromley, 1989, 47 pages. **$12.00 (Microfiche $2.00)**

Paper ME 1989-2 Geology of the Mabou Highlands, by S. M. Barr and A. S. Macdonald, 1989, 65 pages, 1 geological map in pocket. **$15.00 (Microfiche $3.00)**

Paper ME 1989-1 Metallogenic Studies of Southeastern Cape Breton Island, by A. S. Macdonald, 1989, 99 pages, 3 figures in pocket. **$20.00 (Microfiche $3.00)**

Paper ME 1986-1 Cretaceous Deposits of Nova Scotia, by G. B. Dickie, 1987, 54 pages. **$15.00 (Microfiche $3.00)**

Paper ME 1985-2 The Formation of Veins in Greenschist Facies Rocks and the Early Deformation of the Meguma Group, Eastern Nova Scotia, by B. H. O'Brien, 1985, 35 pages. **$3.00 (Microfiche $1.00)**

Paper ME 1984-1 Petrology of Granitoid Rocks of the Boisdale Peninsula, Central Cape Breton Island, Nova Scotia, by S. M. Barr and J. R. D. Setter, 1986, 75 pages, includes Map ME 1984-2 folded in back pocket. **$8.00 (Microfiche $2.00)**

Paper ME 1982-2 Metasomatic-Hydrothermal Mineral Deposits of the New Ross - Mahone Bay Area, Nova Scotia, by G. A. O'Reilly, E. J. Farley and M. H. Charest, 96 pages. **$5.00 (Microfiche $1.50)**

Paper ME 1982-1 Geology and Geochemistry of Selected Granitoid Plutons of Cape Breton Island, by S. M. Barr, G. A. O'Reilly and A. M. O'Beirne, 176 pages, 44 figures, 13 tables. **$8.00 (Microfiche $2.00)**

Paper ME 1981-4 Principles of Tectonic Mapping Based upon Plate Tectonic Theory, by J. D. Keppie, 11 pages. **$1.50 (Microfiche $1.00)**

Paper ME 1981-3 The Windsor Group of the Mahone Bay Area, Nova Scotia, by P. S. Giles, 51 pages, figure in back pocket. **$4.00 (Microfiche $1.50)**

Paper ME 1981-2 Major Transgressive - Regressive Cycles in Middle to Late Viséan Rocks of Nova Scotia, by P. S. Giles, 27 pages. **$2.00 (Microfiche $1.50)**

Paper ME 1981-1 The Fisset Brook Formation at Lowland Cove, Inverness County, Nova Scotia, by P. K. Smith and A. S. Macdonald, 18 pages. **$2.00 (Microfiche $1.00)**

Paper ME 1980-1 Geology of the Cape North Area, Northern Cape Breton Island, Nova Scotia, by A. S. Macdonald and P. K. Smith, 60 pages, 2 maps. **$5.00 (Microfiche $2.00)**

Paper ME 1979-7 Carbonate Banks of the Gays River Formation in Central Nova Scotia, by P. S. Giles, R. C. Boehner and R. J. Ryan, 57 pages, 1 map. **$4.00**

Paper ME 1979-6 Effects of Subsidence and Depositional Environment on the Formation of Lithotypes in a Hypautochthonous Coal of the Pictou Coalfield, by J. H. Calder, 23 pages. **$3.00**

Paper ME 1979-5 Pleistocene Stratigraphy of the Miller Creek Section, Hants County, Nova Scotia, by R. Stea and D. Hemsworth, 16 pages. **$3.00**

Paper ME 1979-4 Minor and Trace Element Variations in Wisconsinan Tills, Eastern Shore Region, Nova Scotia, by R. R. Stea and J. H. Fowler, 30 pages, 3 maps. **$10.00**

Paper ME 1979-3 Geology of the Meat Cove Zinc Deposit, Cape Breton Island, by A. K. Chatterjee, 27 pages. **$2.00**

Paper ME 1979-2 Opencast Coal Reserves at Springhill, by B. Ward, 40 pages, 4 maps. **$4.50**

Paper ME 1979-1 Petrology of the Late Precambrian Fourchu Group in the Louisbourg Area, Cape Breton Island, by J. D. Keppie, J. Dostal and J. B. Murphy, 18 pages. **$1.50**

Paper ME 1978-5 Petrology of the Early Silurian Dunn Point and McGillivray Brook Formations, Arisaig, Nova Scotia, by J. D. Keppie, J. Dostal and M. Zentilli, 20 pages. **$1.00**

Paper ME 1978-4 Some Middle Devonian to Lower Carboniferous Rocks of Cape George, Nova Scotia, by J. D. Keppie, P. S. Giles, and R. C. Boehner, 37 pages. **$2.00**

Paper ME 1978-3 Geology of the Giant Lake Area, Southeastern Cape Breton Island, Nova Scotia, by P. K. Smith, 30 pages, 1 map. **$2.00**

Paper ME 1978-2 Age of Igneous Rocks along the Lennox Passage - St. Peter's Lineament, Southern Cape Breton Island, by J. D. Keppie and P. K. Smith, 10 pages. **$1.00**

Paper ME 1978-1 Geology of the Ecum Secum Area, Halifax and Guysborough Counties, Nova Scotia, by D. McBride, 12 pages. **$1.00**

Paper ME 1977-7 Tungsten Mineralization in the Carbonate Rocks of the George River Group, Cape Breton Island, Nova Scotia, by A. K. Chatterjee, 26 pages. **$3.50**

Paper ME 1977-6 Sand and Gravel Resources of Pictou County, by J. H. Fowler and G. B. Dickie, 42 pages, 1 map. **$4.00**

Paper ME 1977-3 Plate Tectonic Interpretation of Paleozoic World Maps (with Emphasis on Circum-Atlantic Orogens and Southern Nova Scotia), by J. D. Keppie, 45 pages. (Reprinted 1982). **$4.00 (Microfiche $1.50)**

Paper ME 1977-1 Tectonics of Southern Nova Scotia, by J. D. Keppie, 34 pages. (Reprinted 1980). **$3.00**

Paper ME 1976-5 Guide to the Invertebrate Fauna of the Windsor Group in Atlantic Canada, by R. G. Moore and R. J. Ryan, 57 pages. **$2.25**

Paper ME 1976-4 Geology, Geochemistry and Mineral Occurrences of the Northeast Margaree River Drainage Basin in parts of Inverness and Victoria Counties, Cape Breton, Nova Scotia, by B. E. MacNabb, J. H. Fowler and T. G. N. Covert, 30 pages, 12 maps. **$15.00**

Paper ME 1976-3 Interpretation of P.P.I. Radar Imagery of Nova Scotia, by J. D. Keppie, 31 pages, 1 map. **$1.25**

Paper ME 1976-2 Geological Data Collection in the Nova Scotia Department of Mines, by J. D. Keppie and A. K. Chatterjee, 15 pages. **$0.50**

Paper ME 1976-1 Structural Model for the Saddle Reef and Associated Veins in the Meguma Group, Nova Scotia, by J. D. Keppie, 34 pages, 2 maps. **$3.00**

REPORTS

Various geoscience publications such as bibliographies, compilations, drill log summaries, indexes, Report of Activities.

Report ME 1999-2 Mining Matters for Nova Scotia '99: Opportunities for Economic Development, edited by D. R. MacDonald, 1999, 36 pages. **$5.00**

Report ME 1999-1 Minerals and Energy Branch Report of Activities 1998, edited by D. R. MacDonald and K. A. Mills, 1999, 213 pages. **$12.00**

Report ME 1998-2 Mining Matters for Nova Scotia '98: Opportunities for Economic Development, edited by D. R. MacDonald, 1998, 37 pages. **$5.00**

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Report ME 1996-3 NTS Location Index to Minerals and Energy Branch Assessment Reports, Contribution Series, Open Files and Publications 1991-1995, by Janette M. Vavra, Norman A. Lyttle and J. Susan Saunders, 1996, 203 pages. **$11.00 (Microfiche $3.00)**

Report ME 1996-2 Author Index to Minerals and Energy Branch Assessment Reports, Contribution Series, Open Files and Publications 1991-1995, by Janette M. Vavra, Norman A. Lyttle and J. Susan Saunders, 1996, 362 pages. **$17.00 (Microfiche: $4.00)**

Report ME 1996-1 Minerals and Energy Branch, Report of Activities 1995, edited by D. R. MacDonald and K. A. Mills, 1996, 99 pages. **$9.00 (Microfiche $2.00)**

Report ME 1995-2 Program and Summaries, Nineteenth Annual Review of Activities, edited by D. R. MacDonald and K. A. Mills, 1995, 71 pages. **$5.00 (Microfiche $2.00)**

Report ME 1995-1 Minerals and Energy Branch, Report of Activities 1994, edited by D. R. MacDonald and K. A. Mills, 1995, 216 pages. **$14.00 (Microfiche $3.00)**

Report ME 1994-2 Program and Summaries, Eighteen Annual Review of Activities, edited by D. R. MacDonald, 1994, 75 pages. **$5.00 (Microfiche $2.00)**

Report ME 1994-1 Mines and Minerals Branch, Report of Activities 1993, edited by D. R. MacDonald, 1994, 245 pages. **$14.00 (Microfiche $3.00)**

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Report ME 1993-1 Mines and Minerals Branch, Report of Activities 1992, edited by D. R. MacDonald and K. A. Mills, 1993, 203 pages. **$12.00 (Microfiche $3.00)**

Report ME 1992-2 NTS Location and Author Index to Nova Scotia Department of Natural Resources, Mines and Energy Branches Assessment Reports, Contribution Series, Open Files and Publications for 1991, by Janette M. Vavra and Norman A. Lyttle, 1992, 178 pages. **$14.00 (Microfiche $3.00)**

Report ME 1992-1 Mines and Minerals Branch, Report of Activities 1991, ed. D. R. MacDonald, 1992, 122 pages. **$7.00 (Microfiche $2.00)**

Report ME 1991-4 Subject Index to Nova Scotia Department of Mines and Energy Assessment Reports, Open Files, Publications and Theses 1981-1990, by Norman A. Lyttle and Janette M. Freeman, 1991, 5630 pages. **(Microfiche only $5.00)**

Report ME 1991-3 Author Index to Nova Scotia Department of Mines and Energy Assessment Reports, Open Files, Publications and Theses 1981-1990, by Norman A. Lyttle and Janette M. Freeman, 1991, 508 pages. **$20.00 (Microfiche $5.00)**

Report ME 1991-2 NTS Location Index to Nova Scotia Department of Mines and Energy Assessment Reports, Open Files, Publications and Theses 1981-1990, by Norman A. Lyttle and Janette M. Freeman, 1991, 452 pages. **$20.00 (Microfiche $5.00)**

Report ME 1991-1 Mines and Minerals Branch, Report of Activities 1990, ed. D. R. MacDonald, 1991, 140 pages. **$8.00 (Microfiche $3.00)**

Report ME 1990-1 Mines and Minerals Branch, Report of Activities 1989, Part B, ed. D. R. MacDonald, 1990, 112 pages. **$7.00 (Microfiche $2.00)**

Report ME 1989-1 Mines and Minerals Branch, Report of Activities 1988, Part B, eds. Y. Brown and D. R. MacDonald, 1988, 133 pages. **$9.00 (Microfiche $2.00)**

Report ME 1988-1 Mines and Minerals Branch, Report of Activities 1987, Part B, eds. D. R. MacDonald and Y. Brown, 292 pages. **$20.00 (Microfiche $4.00)**

Report ME 1987-4 Drilling Logs of Government Core Drills 1986, compiled by C. Kavanaugh, 1987, 64 pages. **$5.00 (Microfiche $2.00)**

Report ME 1987-2 Gold in Nova Scotia: A Bibliography of the Geology, and Exploration and Mining Histories from 1832 to 1986, by Janet Gillespie-Wood, 1986, 500 pages. **$25.00 (Microfiche $3.00)**

Report ME 1987-1 Mines and Minerals Branch, Report of Activities 1986, eds. J. L. Bates and D. R. MacDonald, 270 pages. **$15.00 (Microfiche $3.00)**

Report ME 1986-3 Drilling Logs of Government Core Drills 1985, compiled by I. MacDougall and D. E. Polley, 1986, 21 pages. **$3.50 (Microfiche $2.00)**

Report ME 1986-1 Mines and Minerals Branch, Report of Activities 1985, ed. J. L. Bates, 374 pages. **$12.00 (Microfiche $3.50)**

Report ME 1985-4 Drilling Logs of Government Core Drills 1984, compiled by I. MacDougall and D. E. Polley, 1984, 32 pages. **$3.50 (Microfiche $2.00)**

Report ME 1985-1 Mines and Minerals Branch, Report of Activities 1984, eds. K. A. Mills and J. L. Bates, 232 pages. **$10.00 (Microfiche $3.00)**

Report ME 1984-6 Bibliography of the Surficial Geology of Nova Scotia and the Offshore (with Radiocarbon Date List), by R. R. Stea and V. J. Brisco, 128 pages. **$6.00 (Microfiche $2.00)**

Report ME 1984-5 Drilling Logs of Government Core Drills 1983, compiled by I. MacDougall and D. E. Polley, 1983, 38 pages. **$3.50 (Microfiche $2.00)**

Report ME 1984-4 Keyword Index to Theses in Report ME 1981-6, by N. A. Lyttle and J. Gillespie-Wood. **(Microfiche only $5.00)**

Report ME 1984-1 Mines and Minerals Branch, Report of Activities 1983, eds. J. Szostak and K. A. Mills, 352 pages. **$10.00 (Microfiche $4.00)**

Report ME 1983-3 Drilling Logs of Government Core Drills 1982, compiled by I. MacDougall and D. E. Polley, 1983, 38 pages. **$3.50 (Microfiche $2.00)**

Report ME 1983-1 Mines and Minerals Branch, Report of Activities 1982, ed. K. A. Mills, 404 pages. **$10.00 (Microfiche $3.50)**

Report ME 1982-7 Uranium in Nova Scotia: A Background Summary for the Uranium Inquiry, Nova Scotia, 122 pages, 2 maps. Out of Print **(Microfiche only $2.00)**

Report ME 1982-6 Drilling Logs of Government Core Drills 1981, compiled by I. MacDougall and D. E. Polley, 1982, 60 pages. **$3.50 (Microfiche $1.50)**

Report ME 1982-5 Keyword Index to Geological Survey of Canada Documents on Nova Scotia to 1980. **(Microfiche only $2.00)**

Report ME 1982-4 Keyword Index to Open File Reports in Nova Scotia Department of Mines and Energy Report ME 1981-6, by N. A. Lyttle and J. Gillespie-Wood. **(Microfiche only $1.00)**

Report ME 1982-3 Keyword Index to Publications in Nova Scotia Department of Mines and Energy Report ME 1981-6, by N. A. Lyttle and J. Gillespie-Wood. **(Microfiche only $2.00)**

Report ME 1982-1 Mineral Resources Division, Report of Activities 1981, ed. K. A. Mills, 139 pages. **$7.00 (Microfiche $2.00)**

Report ME 1981-7 Index to Drillhole and Well Data 1862-1980, by N. A. Lyttle and J. Gillespie-Wood, 127 pages. **$10.00 (Microfiche $3.00)**

Report ME 1981-6 Index to Publications, Open File Reports and Theses, 1862-1980, by N. A. Lyttle and J. Gillespie-Wood, 222 pages. **$10.00 (Microfiche $3.00)**

Report ME 1981-5 Keyword Index to Assessment Reports 1864-1980, by N. A. Lyttle and J. Gillespie-Wood. **(Microfiche only $5.00)**

Report ME 1981-4 Index to Assessment Reports 1864-1980, by N. A. Lyttle and J. Gillespie-Wood, 109 pages. **$10.00 (Microfiche $3.00)**

Report ME 1981-3 Drilling Logs of Government Core Drills 1980, compiled by I. MacDougall and D. E. Polley, 52 pages. **$3.50 (Microfiche $1.00)**

Report ME 1981-2 Compilation of Igneous Chemical Analyses from Nova Scotia, up to 1978, compiled by J. D. Keppie, P. K. Smith and M. A. K. Grice, 114 pages. **$4.00 (Microfiche $2.00)**

Report ME 1981-1 Mineral Resources Division, Report of Activities 1980, ed. K. A. Mills, 199 pages. **$8.00 (Microfiche $2.00)**

Report ME 1980-3 Drilling Logs of Government Core Drills 1979, compiled by I. MacDougall and D. E. Polley, 68 pages. **$3.50 (Microfiche $1.50)**

Report ME 1980-2 Index to Drilling Logs of Government Core Drills 1972-78, by N. A. Lyttle and J. Gillespie-Wood, 47 pages. **$3.00**

Report ME 1980-1 Mineral Resources Division, Report of Activities 1979, 248 pages. **$7.00**

Report ME 1979-2 Drilling Logs of Government Core Drills 1978, by I. MacDougall and D. E. Polley, 54 pages. **$2.00**

Report ME 1979-1 Mineral Resources Division, Report of Activities 1978, 177 pages. **$6.00**

Report ME 1978-4 Compilation of Isotopic Age Data of Nova Scotia, by J. D. Keppie and P. K. Smith, 54 pages, 7 maps. **$7.00**

Report ME 1978-2 Drilling Logs of Government Core Drills 1977, by I. MacDougall and D. E. Polley, 72 pages. **$2.00**

Report ME 1978-1 Mineral Resources Division, Report of Activities 1977, 104 pages. **$4.00**

Report ME 1977-3 Drilling Logs of Government Core Drills 1976, by I. MacDougall and D. W. Grimm, 33 pages. **$1.00**

Report ME 1977-1 Mineral Resources Division, Report of Activities 1976, 207 pages. **$10.00**

Report ME 1976-3 Drilling Logs of Government Core Drills 1975, by I. MacDougall and D. W. Grimm, 47 pages. **$1.00**

Report ME 1976-2 Mineral Resources Division, Report of Activities 1975, 145 pages. **$3.00**

Report ME 1976-1 Drilling Logs of Government Core Drills, 1974, by I. MacDougall and D. W. Grimm, 73 pages. **$1.00**

Report ME 1975-1 Report of Activities of the Mineral Resources and Geological Services Division, 1974, by Nova Scotia Department of Mines, 75 pages. **$1.00**

SAMPLE CATALOGUES

Bound volumes containing rock or mineral commodity samples.

SC ME 1989-1 Nova Scotia Dimension Stone for Designers, Developers and Quarriers, 1989 (Comprehensive catalogue of 11 Nova Scotia building stones, includes actual sample tiles plus Information Series ME 19). **$100.00**

Appendix 3

Minerals and Energy Branch Digital Geoscience Data for Sale

DIGITAL COLLECTIONS	FORMAT	SIZE/MEDIA	PRICE
DC 001. Complete set of Nova Scotia Department of Natural Resources digital geoscience data, version 2, 2000	E00, DXF/DBF, TIFF	167 Mb (compressed), (for individual products, see below) 1 CD-ROM	$10.00
MAPS	**FORMAT**	**SIZE/MEDIA**	**PRICE**
D00-01. Geological Map of the Province of Nova Scotia, Version 1, 2000, compiled by J. D. Keppie, scale 1:500 000. An image of the published map and legend (Map ME 2000-1) is also available in PDF format.	E00 DXF/DBF SHP	5 Mb 6 Mb 6 Mb	
D94-08. Geological Map of Bridgetown, Nova Scotia [21A/14], [1:50 000], version 1, 1997, compiled by M. A. MacDonald and L. J. Ham, 1994 (line work only, no point data)	E00 DXF/DBF	360 Kb 587 Kb	
D94-07. Geological Map of Digby, Nova Scotia [21A/12], 1:50 000, version 1, 1997, compiled by L. J. Ham, 1994 (line work only, no point data)	E00 DXF/DBF	373 Kb 493 Kb	
D94-04. Geological Map of Weymouth, Nova Scotia [21A/05], version 1, 1997, compiled by M. A. MacDonald and L. J. Ham, 1994, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	106 Kb 200 Kb	
D94-03. Geological Map of Wentworth Lake, Nova Scotia [21A/04 and parts of 20P/13], version 1, 1997, compiled by L. J. Ham and M. A. MacDonald, 1994, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	156 Kb 243 Kb	
D94-02. Geological Map of Lake Rossignol, Nova Scotia [21A/03 West], version 1, 1997, compiled by M. C. Corey and R. J. Horne, 1994, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	76 Kb 88 Kb	
D94-01. Geological Map of the South Mountain Batholith, Western Nova Scotia [parts of 11D and 21A], version 1, 1997, compiled by M. A. MacDonald, 1994, scale 1:250 000 (line work only, no point data)	E00 DXF/DBF	1.5 Mb 1.6 Mb	

MAPS (cont.)	FORMAT	SIZE/MEDIA	PRICE
D92-03. Surficial Geology Map of the Province of Nova Scotia, version 1, 1997, compiled by R. R. Stea, H. Conley and Y. Brown, 1992, scale 1:500 000.	E00 DXF/DBF	20 Mb 22 Mb	
D90-14. Cumberland Basin Geology Map Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties, Nova Scotia [11E/11 and 11E/14 south], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	400 Kb 458 Kb	
D90-13. Cumberland Basin Geology Map Oxford and Pugwash, Cumberland County, Nova Scotia [11E/12 and 11E/13], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 763 Kb	
D90-12. Cumberland Basin Geology Map Amherst, Springhill and Parrsboro, Cumberland County, Nova Scotia [21H/08, 21H/09 and 21H/10], version 1, 1997, compiled by R. J. Ryan, R. C. Boehner, A. J. Deal and J. H. Calder, 1990, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 600 Kb	
D90-11. Cumberland Basin Geology Map, Apple River and Cape Chignecto, Cumberland County, Nova Scotia [21H/07 and 21H/10], version 1, 1997, compiled by R. J. Ryan and R. C. Boehner, 1990, 1:50 000 (line work only, no point data)	E00 DXF/DBF	300 Kb 408 Kb	
D86-02. Geological Map of the Windsor Area, Nova Scotia [21A/16 north and 21H/01 south], version 1, 1997, compiled by R. G. Moore and S. A. Ferguson, 1986, 1:25 000 (line work only, no point data)	E00 DXF/DBF	864 Kb 832 Kb	
D86-01. Geological Map of the Sydney Basin-Cape Breton, Nova Scotia [11K/01, 11K/08 and 11J/04], version 1, 1997, compiled by R. C. Boehner and P. S. Giles, 1986, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	1.2 Mb 1.6 Mb	
D85-02. Geology of Loch Lomond Basin and Glengarry Half Graben, Nova Scotia [11F/15 east and 11F/16 west], version 1, 1997, compiled by R. C. Boehner and G. Prime, 1985, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 610 Kb	
D85-01. Industrial Mineral Commodities Map of the Province of Nova Scotia, version 1, 1997, compiled by J. H. Fowler, 1985, scale 1:500 000.	E00 DXF/DBF	200 Kb 200 Kb	

MAPS (cont.)	FORMAT	SIZE/MEDIA	PRICE
D84-02. Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia [parts of 11F/15, 11F/16, 11K/01 and 11K/02], version 1, 1997, compiled by S. M. Barr and J. R. D. Setter, 1984, scale 1:100 000 (line work only, no point data)	E00 DXF/DBF	258 Kb 371 Kb	
D83-05. Metallogenic Map of Nova Scotia, version 1, 1997, compiled by A. K. Chatterjee, 1983, scale 1:500 000 (includes the inset map **Metallogenic Associations and Domains of Silver**, scale 1:1 000 000).	E00 DXF/DBF	4 Mb 6 Mb	
D83-01. Geological Map of the Hantsport Area, Nova Scotia [21H/01], version 1, 1997, compiled by S. A. Ferguson, 1983, scale 1:25 000 (line work only, no point data)	E00 DXF/DBF	459 Kb 609 Kb	
D82-09. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 4 of 4 [11E/06, 11E/07 west and 11E/10 west], version 1, 1997, compiled by H. V. Donohoe, Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 649 Kb	
D82-08. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 3 of 4 [11E/05 and 11E/12], version 1, 1997, compiled by H. V. Donohoe, Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	500 Kb 690 Kb	
D82-07. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 2 of 4 [21H/08 and 21H/09], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	600 Kb 650 Kb	
D82-06. Geological Map of the Cobequid Highlands-Colchester, Cumberland and Pictou Counties, Nova Scotia, sheet 1 of 4 [21H/07], version 1, 1997, compiled by H. V. Donohoe Jr. and P. I. Wallace, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	400 Kb 391 Kb	
D82-05. Geology Map of the Northern Antigonish Highlands, Nova Scotia [11E/09, 11E/16, 11F/12 and 11F/13], version 1, 1997, compiled by J. B. Murphy, J. D. Keppie and A. H. Hynes, 1991, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	38 Kb 38 Kb	

MAPS (cont.)	FORMAT	SIZE/MEDIA	PRICE
D82-04. Geological Map of the Shubenacadie and Musquodoboit Basins, Central Nova Scotia [11D/13, 11D/14, 11E/02 west, 11E/04 east and 11E/03], version 1, 1997, compiled by P. S. Giles and R. C. Boehner, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	1 Mb 1.4 Mb	
D82-03. Geological Map of the Eureka Area, Central Nova Scotia [11E/07D and 11E/10A], version 1, 1997, compiled by P. S. Giles, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	200 Kb 195 Kb	
D82-02. Geological Map of the Antigonish Basin, Nova Scotia [parts of 11E/09, 11F/12 and 11F/13], version 1, 1997, compiled by R. C. Boehner and P. S. Giles, 1982, scale 1:50 000 (line work only, no point data)	E00 DXF/DBF	691 Kb 920 Kb	
D79-03. Bouguer Gravity Anomaly Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:500 000.	E00 DXF/DBF	1 Mb 2 Mb	
D79-01S. Structural Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:1 000 000 (insert from Map 79-1)	E00 DXF/DBF	1 Mb 1.5 Mb	
D79-01M. Metamorphic Map of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:1 000 000 (insert from Map 79-1)	E00 DXF/DBF	700 Kb 1 Mb	
D79-01. Geological Map of the Province of Nova Scotia, version 1, 1997, compiled by J. D. Keppie, 1979, scale 1:500 000 (does not include the 1:1 000 000 structural and metamorphic inset maps).	E00 DXF/DBF	5 Mb 6 Mb	
D1752a. Geological map of northern Cape Breton Island, Nova Scotia [11K/02, 11K/03, 11K/06 to 11K/16, 11N/01, 11N/02] [1:100 000], version 1, 1997, compiled by S. M. Barr, R. A. Jamieson, R. P. Raeside, 1992, Geological Survey of Canada, Map 1752a.	E00 DXF/DBF	2 Mb 2 Mb	

DATABSES	FORMAT	SIZE/MEDIA	PRICE
DP 001a. Mineral occurrence query program, version 2, 1997. (This is a viewing and searching program with instructional manual (40 pages) for use with DP 001b Mineral Occurrence Database)	EXE	3 Mb	

DATABSES (cont.)	FORMAT	SIZE/MEDIA	PRICE
DP 001b. Mineral occurrence database, version 3, 1998. This database can be used with DP 001a, the Mineral Occurrence Query Program.	DBF	7 Mb	
DP 002. Mineral occurrence database, version 3, 1998.	E00	4 Mb	
	DXF/DBF	7 Mb	
DP 003. Drillholes database, version 2, 2000.	E00	55 Mb	
	DXF/DBF	16 Mb	
	SHP	55 Mb	
DP 004. Regional geochemical datasets (biogeochemical, lake and stream sediment, lake and stream water, soil, rock and till geochemical surveys), version 1, 1996.	E00	24 Mb	
	DXF/DBF	19 Mb	
DP 009. Claim reference map grid, Nova Scotia, version 1, 1997.	E00	1.4 Kb	
	DXF/DBF	1.2 Kb	
DP 010. Abandoned mine openings database, version 2, 2000.	E00	4 Mb	
	DXF/DBF	3 Mb	
	SHP	4 Mb	
IMAGES	**FORMAT**	**SIZE/MEDIA**	**PRICE**
DP 005. Airborne gamma ray spectrometric survey images, elemental and elemental ratio images covering 11D, 11E, 11F, 11G, 11J, 11K, 11N, 20O, 20P, 21A, 21B and 21H), version 1, 1997 (250 m x 250 m resolution).	TIFF	14 Mb	
DP 006. Airborne magnetometer survey images, total field and vertical gradient images covering 11D, 11E, 11F, 11G, 11J, 11K, 11N, 20O, 20P, 21A, 21B and 21H, version 1, 1997 (250 m x 250 m resolution).	TIFF	8 Mb	
DP 007. Airborne synthetic aperture radar (SAR) images covering 11D, 11E/01, 11E/02, 11E/03 and 11E/04, version 1, 1997, (6 images, 25 m x 25 m resolution).	TIFF	59 Mb, CD-ROM	$10.00

IMAGES (cont.)	FORMAT	SIZE/MEDIA	PRICE
DP 008. Meguma Terrane enhanced second vertical derivative aeromagnetic digital data, version 1, 1997. Includes: (a) images in TIFF format of the aeromagnetic data from OFM's 97-7 to 97-28 and 97-30 to 97-33, without topographic base information or legends; (b) contractor's report on the processing methodology; (c) plot files in HP-GL/2 format of OFM's 97-7 to 97-28 and 97-30 to 97-33.	TIFF	573 Mb, CD-ROM	$10.00
DP 011 Enhanced Aeromagnetic and Digital Elevation Image of Eastern Nova Scotia, Version 1, 2000, M. S. King, (25 m x 25 m, 40 m x 40 m, 80 m x 80 m resolutions) (TIFF Format).	TIFF	100 Mb/14 Mb/5 Mb, CD-ROM	$10.00